Phytopathology

An International Journal

Official Organ of

THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

THE UNIVERSITY OF MICHIGAN
FEB 27 1961
SCIENCE LIBRARY

VOLUME 50 DECEMBER, 1960 NUMBER 12

Howard Austin Edson, 1875-1960 ..... Paul R. Miller 869

Selectivity of fungicidal materials in agar cultures ..... O. Vaartaja 870

Species differentiation of nematodes through host reaction in tissue culture. I. Comparisons of Meloidogyne hapla, Meloidogyne incognita incognita, and Nacobbus batatiformis
M. L. Schuster and T. Sullivan 874

Development of western gall rust in lodgepole pine ..... R. S. Peterson 876

Specialization among greenbugs in the transmission of barley yellow dwarf virus ..... W. F. Rochow 881

Some effects of 8-azaguanine on tobacco mosaic virus replication
R. C. Lindner, P. C. Cheo, H. C. Kirkpatrick, and H. C. Govindu 884

Relationships among isolates of Pseudomonas syringae pathogenic on stone fruit trees
Gerardo Perlasca 889

The black shank-root-knot complex in flue-cured tobacco ..... N. T. Powell and C. J. Nusbaum 899

Bacterial stripe of corn ..... A. J. Ullstrup 906

The role of infested straw in the epiphytology of Septoria leaf blotch of barley
Richard W. Lutey and Karl D. Fezer 910

Host-parasite interactions of eight varieties of oats infected with race 202 of Puccinia coronata var. avenae ..... P. G. Rothman 914

News

Index for 1960

Errata

Table of Contents for 1960

Office of Publication—Monumental Printing Company, Baltimore. Md.
Subscription, $15.00 per year. Second class postage paid at Baltimore, Md.

DITHANE M-22

Now, more than ever, DITHANE M-22 gives growers most effective protection against tomato diseases, and greatest assurance of higher yields and bigger profits. This time-proved 80% maneb fungicide controls early and late blight, anthracnose, gray leaf spot and septoria leaf spot on tomatoes. It also improves the vigor and color of the plants . . . making bigger yields possible. To kill fruitworm, hornworm, pinworm and psyllid on tomatoes, RHOTHANE insecticide is recommended.

DITHANE *and* RHOTHANE *are trademarks, Reg. U.S. Pat. Off. and in principal foreign countries.*

Chemicals for Agriculture

ROHM & HAAS COMPANY

WASHINGTON SQUARE, PHILADELPHIA 5, PA.

HOWARD AUSTIN EDSON, 1875–1960

Paul R. Miller

Howard Austin Edson, a charter and life member of the American Phytopathological Society, died February 29, 1960, in Washington, D. C., at the age of 84.

Dr. Edson had a long career in the Federal government. For about 6 years, 1927–33, he was Chief Examiner in the Civil Service Commission. Except for that interlude he was employed by the Department of Agriculture, in the old Bureau of Plant Industry and its successors, from 1910 until his retirement, in 1945. His first appointment was as Physiologist in the Office of Cotton, Truck, and Forage Crop Disease Investigations. In 1924 he became Senior Pathologist in Charge of that Office. When his service as Chief Examiner ended, Dr. Edson returned to the Bureau of Plant Industry as Principal Pathologist in Charge, Division of Mycology and Disease Survey. He remained head of the Division until he retired. During the two years just before his retirement he was also responsible for the Emergency Plant Disease Prevention Program, a country-wide crop protection service operated by the Department of Agriculture under special authorization in 1943–45. The speedy organization and successful administration of the Program were an extraordinary achievement and a fitting climax to Dr. Edson's career in the Department.

Dr. Edson was born August 14, 1875, at Randolph, Vermont. He was educated in the Vermont public schools, Vermont State Normal School, the University of Vermont, and the University of Wisconsin. Before entering the University of Vermont he had some 5 years of varied farm, mercantile, and teaching experience. He received the B.S. degree in 1906 and the M.S. degree in 1910 from the University of Vermont, and the Ph.D. degree in 1913 from the University of Wisconsin. While doing graduate work at the University of Vermont he held various teaching and research positions. His University training was largely in chemistry, physiology, and bacteriology.

Dr. Edson thoroughly enjoyed his varied types of research in the Office of Cotton, Truck, and Forage Crop Disease Investigations. He was most interested in biochemical studies on fungus nutrition and metabolism in relation to parasitism. His contributions to knowledge on this topic were fundamental. He also investigated diseases of sugar beet, potato, and other vegetables. In 1914 he was sent to Europe to study sugar beet and potato diseases there, and in 1916 he made a plant disease survey in the Philippine Islands.

In spite of his excellent research record, Dr. Edson became most noted for his outstanding ability in administration and his active interest in personnel relations. Twice during the early part of his Departmental career he was detailed to work with groups studying reclassification of scientific positions and allocation of scientific personnel. His appointment as Chief Examiner in the Civil Service Commission was a natural sequel to his work on reclassification. To a greater degree than most other scientists, Dr. Edson possessed interest in personnel problems, capacity for objective appraisal, and talent for administration, besides an intimate knowledge of scientific requirements, all qualities indispensable for setting up standards of scientific accomplishment and only rarely combined in one person.

Dr. Edson's interest in personnel welfare was not limited to administration but included the employee's outlook as well. He was active in the National Federation of Federal Employees, an employee union, both throughout his government service and after retirement, and he was instrumental in establishing and building up the Agricultural Employees' Credit Union.

Dr. Edson was Treasurer and Business Manager of the American Phytopathological Society from 1935 to 1943, a time of economic stress during which his guidance maintained the Society on a sound financial basis. There was plenty of opposition to his financial policy, and many members objected strenuously to what they considered his excessive caution. Dr. Edson regarded good investment and saving as important to the future welfare of the Society. His firm stand made him unpopular for a time, but in the long run the Society was undoubtedly the gainer.

HOWARD AUSTIN EDSON
1875–1960

Other scientific groups to which Dr. Edson belonged included the Washington Academy of Science, the Botanical Society of America, the Washington Botanical Society, the Vermont Botanical Society, the American Association for the Advancement of Science, of which he was a fellow, the Cosmos Club of Washington, and the honor societies Phi Beta Kappa, Sigma Xi, and Phi Delta Theta.

Dr. Edson was a member of the National Presbyterian Church, which he served as elder for 30 years, and a commissioner of the Washington Presbytery.

In 1956 Dr. Edson and his wife, the former Miss Lillian Buck of Vermont, celebrated their fiftieth wedding anniversary. Mrs. Edson died the following year. A daughter, a son, and several grandchildren survive.

Dr. Edson was basically a friendly person, but he had his share of New England reserve and determination. The qualities that most impressed all who knew him were his magnanimity, his frankness, and above all his complete integrity.

SELECTIVITY OF FUNGICIDAL MATERIALS IN AGAR CULTURES

O. Vaartaja

Contribution No. 615, Forest Biology Division, Research Branch, Department of Agriculture, Ottawa, Canada, and No. 41, Canada Department of Agriculture Research Station, Saskatoon, Saskatchewan.

Accepted for publication May 16, 1960.

SUMMARY

Tolerance of fungi to synthetic and natural fungicidal materials was studied in agar cultures. Many of the 43 materials exerted selective action on 10 species representing different fungal groups. *Pythium debaryanum* and *Phytophthora cactorum* tolerated 3 polyene antibiotics at concentrations inhibitory to other species tested, and were inhibited by aureomycin at rates tolerated by most others. *Phytophthora cactorum* tolerated tannins and certain fungicides better than *P. debaryanum*. *Rhizopus stolonifer* was inhibited by pentachloronitrobenzene at concentrations tolerated by all others. *Trichoderma viride* was inhibited by a duramycin mixture at concentrations tolerated by all others. *Pellicularia praticola* tolerated many materials better than most of the fungi, but with 2 experimental fungicides (B-856 and C-272), captan, and Dyrene the situation was reversed. *Russula* sp. tolerated duramycin mixture, Dyrene, neomycin, and thiram at concentrations inhibitory to *Mucor ramannianus*. This selectivity might be utilized in isolating pathogens and in indirect biological disease control with fungicides tolerated by antagonistic saprophytes.

In studies of fungal soil flora by the plate technique, rose bengal at about 30 ppm may be used to inhibit many bacteria and actinomycetes. Smith and Dawson (18) found it more useful than boric acid, benzoic acid, or Chrysoidine Y. Rose bengal (18), crystal violet (9), and oxgall (13) have the additional advantage of reducing the spread of many fast-growing fungi, such as *Rhizopus* and *Trichoderma* spp. Bacteria are further inhibited when streptomycin at 30–100 ppm is combined with some of these, usually with rose bengal. Such combinations are now widely used in soil platings (9, 11, 12). Penicillin G (2), aureomycin (3, 8), and novobiocin (7) have been used in the same way as streptomycin. In isolating basidiomycetes from soil, Warcup (20) added either streptomycin or wheat straw to the media to suppress bacteria.

Selective chemicals should also be useful in isolating root pathogens from soil or infected plants. Maloy and Alexander (10) thus isolated *Thielaviopsis basicola* (Berk. & Br.) Ferr. from soil by using carrot tissue soaked in a streptomycin solution as "bait." Nadakavukaren and Horner (14) used agar containing streptomycin and alcohol (5500 ppm) in isolating *Verticillium albo-atrum* Reinke & Berth. from soil. Papavizas and Davey (15) isolated *Rhizoctonia solani* Kühn with pieces of *Fagopyron* as bait plated on media containing 50 ppm of aureomycin, neomycin, and streptomycin.

It should also be possible to suppress certain fungi and select others by using selective fungicides. Barker and Martinson (1) used pentachloronitrobenzene to prevent *Rhizopus stolonifer* (Ehr. ex Fr.) Lindau from overgrowing other fungi in soil sampling tubes. Vaartaja (19) found that several compounds were more effective against *Pythium debaryanum* Hesse than against *Pellicularia praticola* (Kotila) Flentje in a fungicide test on corn-meal agar. Reavill (16) found that chloronitrobenzenes were tolerated better by *Pythium* spp. than by species of several other fungal genera. Schneider (17) used cycloheximide and streptomycin in isolating *Graphium ulmi* Schwarz from wood; this fungus was suppressed less than various contaminants.

This study describes a systematic effort to demonstrate the selective effects of a variety of chemicals on isolates representing different fungal groups.

Methods.—Antibiotic materials and synthetic compounds of chemically different types were selected. The following 43 materials were tested, each at 4 concentrations:

Acti-dione, cycloheximide (3-[2-(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl]glutarimide) at 4, 20, 100, 500 ppm (provided by Upjohn Company); *Albamycin* (novobiocin), antibiotic at 4, 20, 100, 500 ppm (Upjohn Company); *Anisomycin*, antibiotic at 4, 20, 100, 500 ppm (Chas. F. Pfizer Company); *aureomycin*, chlortetracycline (7-chloro-4-dimethylamino-1,4,4a,5,5a,6,11,12a-octahydro-3,6,10,12,12a-pentahydroxy-6-methyl-1,11-dioxo-2-naphthacenecarboxamide) at 0.2, 1, 5, 25 ppm; *B-856*, 1,3-dichloro-5,5-diphenylhydantoin at 2, 10, 50, 250 ppm (Ethyl Corporation); *B(ayer) 22555*, *p*-dimethylaminobenzendiazo sodium sulfonate at 3, 14, 70, 350 ppm (Chemagro Corporation);

Table 1.—Effects of 2 antibiotics on growth of the test fungi in corn-meal agar.

Fungus	Daily radial growth rate (mm)								
	Control medium	With Mycostatin [a]				With Acti-dione [a]			
		VL	L	H	VH	VL	L	H	VH
Rhizopus stolonifer	21	4.5	1	0	0	14	9.3	1	0
Trichoderma viride	17	1.5	0	0	0	3	2	0	0
Fusarium solani	3.5	2.7	1.7	0	0	3	2.1	.5	0
Rhizoctonia solani	8	0	0	0	0	7.3	3.3	0	0
Streptomyces sp.	.2	.2	.2	.2	.2	.2	.2	.2	.2
Pythium debaryarum	14	14	14	12	10	0	0	0	0
Phytophthora cactorum	3.8	3.8	3.3	3.6	1.7	0	0	0	0
Thielaviopsis basicola	1.1	1.1	.7	0	0	0	0	0	0
Mucor ramannianus	2.3	1.3	0	0	0	2.0	1.4	.6	0
Russula sp.	1.1	1	0	0	0	0	0	0	0
Boletus granulatus	0.9	0.3	0	0	0	0	0	0	0

[a] Concentration of these antibiotics: VL (very low) = 4 ppm; L (low) = 20 ppm; H (high) = 100 ppm; VH (very high) = 500 ppm.

captan, *N*-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide at 2, 10, 50, 250 ppm; *catechol* at 4, 20, 100, 500 ppm; *cinnamic acid* at 4, 20, 100, 500 ppm; *coumarin* at 4, 20, 100, 500 ppm; *C-272*, *trans*-1,2-bis(ethylsulfonylethylene) at 0.8, 4, 20, 100 ppm (Chemagro Corporation); *dimethyl formamide* at 4, 20, 100, 500 ppm; *d-sorbitol* at 4, 20, 100, 500 ppm; *duramycin*, a mixture of antibiotics called F-17 and largely containing duramycin, at 4, 20, 100, 500 ppm (Northern Utilization Research Branch, U. S. Department of Agriculture, Peoria, Ill.); *Dyrene*, 2,4-dichloro-6-(*o*-chloroanilino)-2-triazine at 2, 10, 50, 250 ppm (Chemagro Corporation); *ethyl alcohol* at 8, 40, 200, 1,000 ppm; *gallic acid* at 4, 20, 100, 500 ppm; *gladiolic acid*, antibiotic at 2, 10, 50, 250 ppm; *griseofulvin*, antibiotic at 4, 20, 100, 500 ppm; *Karathane*, 2-(1-methylheptyl)-4,6-dinitrophenyl crotonate and isomers, at 0.9, 4.5, 23, 46 ppm; *Mycostatin* (nystatin), polyene antibiotic at 4, 20, 100, 500 ppm; *neomycin*, antibiotic at 3, 15, 75, 350 ppm; *nootkatin*, antibiotic at 4, 20, 100, 500 ppm (Forest Products Laboratory, Vancouver, B. C.); *oligomycin*, antibiotic at 4, 20, 100, 500 ppm (Chas. F. Pfizer Company); *PCNB*, pentachloronitrobenzene at 3, 15, 75, 350 ppm; *phytoactin*, polypeptide antibiotic at 1, 5, 25, 125 ppm (Pabst Laboratories); *pimacrin*, polyene antibiotic at 4, 20, 100, 500 ppm; *pinosylvin*, antibiotic at 4, 20, 100, 500 (Dr. Erdtman, Stockholm, Sweden); *pinosylvin monomethyl ether* (as pinosylvin); *pyrogallol* at 4, 20, 100, 500 ppm; *Rimocidin*, polyene antibiotic at 4, 20, 100, 500 ppm (Chas. F. Pfizer Company); *rose bengal* at 4, 20, 100, 500 ppm; *sodium metabisulfate* at 4, 20, 100, 500 ppm; *sodium propionate* at 4, 20, 100, 500 ppm; *sodium taurochocolate* at 4, 20, 100, 500 ppm; *spruce bark* (powder *from Picea glauca* (Moench) Voss, at 8, 40, 200, 1000 ppm; *streptomycin sulfate* at 4, 20, 100, 500 ppm; *tannic acid* at 4, 20, 100, 500 ppm; *taxifolin*, antibiotic at 4, 20, 100 500 ppm (Forest Products Laboratory, Vancouver, B. C.); *thiram*, bis(dimethylthiocarbamoyl) disulfide at 3, 15, 75, 350 ppm; *thujaplicin*, antibiotic at 4, 20, 100, 500 ppm (Forest Products Laboratory, Vancouver, B. C.); *ustilagic acid*, antibiotic at 4, 20, 100, 500 ppm (Dr. R. Haskins, National Research Council, Prairie Regional Laboratory, Saskatoon, Sask.), *zineb*, zinc ethylenebis[dithiocarbamate] at 2.6, 13, 65, 325 ppm.

The materials were mixed in melted corn-meal agar cooled to about 60°C and immediately poured into Petri dishes. The dishes were seeded with the following species.

1) *Rhizopus stolonifer*, saprophyte, common aerial contaminant; 2) *Trichoderma viride* Pers. ex Fr., saprophyte, very common in most soils; 3) *Fusarium solani* (Mart.) App. & Wr., saprophyte, very common in most agricultural soils; 4) *Rhizoctonia solani* (perfect stage: *Pellicularia praticola*), virulent seedling pathogen, common in many forest nurseries and perhaps in many agricultural soils; 5) *Streptomyces* sp., saprophyte with strongly antagonistic ability against a large number of other fungi, common in neutral and alkaline soils; 6) *Pythium debaryanum*, virulent unspecialized seedling pathogen, very common in most agricultural soils; 7) *Phytopthora cactorum* (Leb. & Cohn) Schroet., unspecialized pathogen, common in certain agricultural soils; 8) *Thielaviopsis basicola*, unspecialized pathogen, common in certain agricultural soils; 9) *Mucor ramannianus* Möller, saprophyte and epiphyte, very common in forest soils; 10) *Russula* sp., possibly a mycorrhizal fungus, common in forest soils.

These isolates originated in Saskatchewan or Manitoba from diseased tree seedlings in forest nursery soils, except that no. 1 was from a pine seed, no. 2 from a orchid root, and no. 10 from a fruiting body.

All the chemicals were tested once with these 10 isolates. The most interesting findings were retested in at least 5 replications. Some of the chemicals were also tested with further isolates of these and other fungal species, as reported in more detail in the results. Among these was *Boletus granulatus* (L.) Fr. (Table 1), a common mycorrhizal fungus. The isolate was obtained from a fruiting body in Saskatchewan.

The cultures were incubated at room temperature. When the control colonies of an isolate reached about half the diameter of the plate, the radial growth was measured for all tests of the isolate. Records of the lowest concentrations totally inhibitory and of those

Table 2.—Concentration[a] of antibiotics and fungicides required to inhibit various fungi.

Material	*Rhizopus stoloniter*	*Trichoderma viride*	*Fusarium solani*	*Rhizoctonia solani*	*Streptomyces* sp.	*Pythium debaryanum*	*Phytophthora cactorum*	*Thielaviopsis basicola*	*Mucor ramannianus*	*Russula* sp.
PCNB	VL[b]	[illegible]	[illegible]	–	–	–	–	–	VH[c]	L
Duramycin	VH[p]	L[b]	–[c]	H[p]	H[p]	VH[c,p]	VH[c,p]	H[p]	H[p]	VH[p]
Rimocidin	VL[b]	VL[b]	L	VL[b]	L	–[c]	–[c]	L	L	L
Pimacrin	L[b,p]	H[p]	L	L[b,p]	–[c]	–[c]	–[c]	L[b,p]	L[b,p]	H[p]
Mycostatin	H[p]	L[b,p]	H	VL[b]	–[c]	–[c]	–[c]	H[p]	L	L[p]
B-856	–	–	VH	VL[b]	H	L[p]	H[p]	H[p]	VH	VH[p]
Captan	–	–	–[p]	L[b]	H	H	H[p]	L[b]	H	H
Dyrene	H[p]	VH[p]	–[p]	L[p,b]	L[b]	–[p]	VH[p]	H[p]	L[b,p]	H[p]
Albamycin	–[p]	–[p]	–	–	VL[b]	VH[p]	VH[p]	–	–	–
Rose bengal	–[p]	–[p]	–[p]	–[p]	L[b]	VH[p]	VH[p]	VH[p]	H	VH[p]
Streptomycin	–	–	–	–	VH[b]	–	–	–	–	–
Neomycin	–[p]	–[c]	–[p]	–[c]	VH[b]	–[p]	–[p]	–[c]	VH[b]	–
Aureomycin	–	–	–	–	H[b,p]	VH[c,p]	VH[b,p]	–[p]	–	–
C-272	–	–[p]	–[p]	VH	L[b]	L[b,p]	L[b]	H	VH	H
Thiram	L	H[p]	L	L[p]	L	VL[b]	L	L	VL[b]	H[p]
Catechol	–	VH	–	VH[p]	VH[p]	H[b]	VH	VH[p]	VH	H[p]
Tannic acid	–	–	–	–	VH	VH[b]	–	VH	–[p]	VH[p]
Gallic acid	–	–	–	VH	–[p]	VH[b]	–	VH[b]	–	VH
Pyrogallol	–	–[p]		VH[p]	VH[p]	L[b]	H[p]	L[b]	H	H
Sodium metabisulfate	VH[p]	–	H[b]	VH[c,p]	H	H[b]	H[b,p]	H[p]	H[p]	H[p]
Actidione	VH[p]	H[b]	VH[p]	H	–	VL[b]	VL[b]	VL[b]	VH[p]	VH
B. 22555	VH[p]	–[c]	–[c,p]	H	VH	H	H[p]	VH	–[p]	H
Zineb	VH	VH	VH	VH[p]	VH	VH	H[b]	H[b]	VH	VH[p]
Ustilagic acid	H	–[c,p]	VH[p]	VH[p]	H	VH	H	L[b]	VH	H
Thujaplicin	L[p]	H[p]	H[p]	L	VL	L	L[p]	VL	L	VL
Karathene	–[p]	VH[p]	–	VH	–	–	–	H[p]	VH[p]	L

[a] Inhibition was complete at concentrations given. The concentrations VH (very high), H (high), L (low), and VL (very low) varied for each material as listed in the text.
[b] Particularly effective inhibition.
[c] Unusual tolerance.
[p] Partial inhibition (growth rate reduction > 75%) at any lower concentration.
– indicates no inhibition at VH.

allowing only limited (< 25%) growth were tabulated for all materials.

Results and discussion.—Table 1 gives examples of actual growth rates and types of selectivity. Table 2 compares most of the materials, excluding those with little or no selectivity.

The selective materials in Table 2 are arranged as closely as possible so that those mainly inhibitory to the isolates on the left are given first. Thus, the first material, PCNB, inhibited the first isolate, *R. stolonifer* at the lowest concentration tested but had no effect on most of the other isolates; the second material, duramycin mixture, was especially effective on the second isolate, *Trichoderma viride;* and so on.

Rimocidin, pimacrin, and Mycostatin, which were tolerated by *Pythium debaryanum* and *Phytophthora cactorum*, belong to the polyene group of antibiotics. The results suggest that these may be used in isolating fungi of this group. Further tests were made with 6 more isolates of *Pythium* spp. and *P. cactorum* and miscellaneous other fungi. The results indicate that the tolerance is common in, and mainly limited to, this group of fungi. Only one of the other isolates, *Mucor* sp., tolerated these antibiotics almost as well as *Pythium*.

It was found that heat destroys polyene antibiotics. According to Dekker and Ark (4) these compounds may be oxidized in the presence of water and oxygen, but the oxidation is counteracted by ascorbic acid, gallic acid, and other compounds. In consideration of the risk of oxidization, a high concentration should be used in isolations. Most Pythiaceae tolerated concentrations of about 500 ppm.

The results in Table 2 as well as in tests with 6 other isolates suggest that *Phytophthora cactorum* can be separated from the usually faster-growing *Pythium* spp. through its better tolerance of C-272, thiram, and tannins (tannic acid, gallic acid, catechol, pyrogallol). It remains to be seen whether this is true with all isolates and species of these genera.

The high activity of PCNB on *R. stolonifer*, referred to in the introduction, was confirmed. Unfortunately, an isolate of *Mucor* sp. tolerated PCNB somewhat better. This chemical reduced but did not inhibit the growth of many fungi. The reduction was especially pronounced with *Trichoderma viride*

These results, as well as those published earlier (5, 19), show that *Rhizoctonia solani* can be selected by suppressing other fungi with various chemicals. One possibility, for instance, is to use a medium containing aureomycin (at 500 ppm) against bacteria, *Streptomyces*, and Pythiaceae, and PCNB (20 ppm) against *R. stolonifer* and *Trichoderma* spp. An isolate of *Rhizoctonia repens* Bernard from roots of *Goodyeara* sp. behaved similarly to the *R. solani* (*P. praticola*) in the tables.

Selective isolation of such slow-growing fungi as *Thielaviopsis basicola* is especially difficult. It might be done, however, with a medium containing various combinations of several materials. Further testing is needed to determine the best concentrations. The results in Table 2 suggest a combination of Mycostatin, Dyrene, or B-856 (against *R. solani*), PCNB (against *R. stolonifer* and *T. viride*), and neomycin (against Pythiaceae and *Fusarium solani*).

The few materials selectively effective (but only to a limited degree) against *Fusarium solani* were neomycin at 500 ppm, PCNB at 250 ppm, and sodium metabisulfate (to select *Rhizoctonia solani* at 100 ppm).

The few tests for materials selective against *Gliocladium* sp. and *Penicillium* spp. were mostly unsuccessful. Some promise was shown by PCNB, duramycin, zineb, and Karathane. The duramycin preparation used contained other antibiotics as well. The promising results obtained should be retested with purer materials. Hampton and Buckholtz (6) reported that coumarin stimulates sporulation of *Pythium graminicolum* Subramaniam. That was not so with *P. debaryanum* in my tests.

Mucor ramannianus was included to test for selective inhibition in isolations from mycorrhizae of forest trees. *M. ramannianus* is common on tree roots and grows faster than mycorrhizal fungi. The results suggest that thiram, neomycin, Dyrene, pimacrin, and duramycin may be selective if used at exactly the right concentrations. Further tests with various isolates of basidiomycetes showed, however, that the only (possibly) mycorrhizal isolate (*Russula* sp.) used with all the chemicals cannot represent all the variety of responses in these fungi. Differing from *Russula* sp., isolates of *Boletus granulatus* and *B. luteus* L., for instance, were greatly inhibited by 10 ppm of pimacrin but tolerated 10 ppm of Rimocidin well. These were stimulated by 8 and 40 ppm of captan, which contains plenty of nitrogen. This suggests that further tests should be made with a richer medium.

The results in the tables also suggest useful selectivity in disease control. If a soil fungicide suppressed the main pathogen but not the antagonistic saprophytes, it may exert an indirect biological control in addition to the direct one (19). Such appears possible especially with Mycostatin, B-856, captan, and Dyrene (against *Rhizoctonia*), thiram, the tannins, Albamycin (novobiocin), Acti-dione, B-22555 (against Pythiaceae), and zineb, ustilagic acid, thujaplicin, and Karathane (against *T. basicola*). Albamycin (novobiocin) may be especially useful against *Streptomyces scabies* (Thaxter) Waksm.—Forest Biology Laboratory, Canada Agriculture Research Station, Saskatoon, Saskatchewan, Canada.

LITERATURE CITED

1. Baker, R., and C. Martinson. 1959. The isolation of fungi by means of the soil microbiological sampling tube. Proc. Intern. Botan. Cong. 9th Cong. 2:15.
2. Bakerspiegel, A., and J. J. Miller. 1959. Comparison of oxgall, crystal violet, streptomycin, and penicillin as bacterial growth inhibitors in platings of soil fungi. Soil Sci. 76:123-126.
3. Cooke, W. B. 1954. The use of antibiotics in media for the isolation of fungi from polluted water. Antibiotics & Chemotherapy 4:657-662.
4. Dekker, J., and P. A. Ark. 1959. Prevention of oxidative destruction of the antifungal antibiotic, pimacrin, by chlorophyll, ascorbic acid, and other compounds (Abstr.). Phytopathology 49:113.
5. Domsch, K. H. 1958. Die Wirkung von Bodenfungiziden I. Wirkstoff-spektrum. Z. Pflanzenkrankh. u. Pflanzenschutz 65:385-405.
6. Hampton, R. O., and W. F. Buchholtz. 1959. Seasonal occurrence of Pythium graminicolum on roots of field grown corn. Iowa State Coll. J. Sci. 33:489-495.
7. Hine, R. B., and E. E. Butler. 1957. Use of novobiocin for isolation of fungi from the soil (Abstr.). Phytopathology 47:524.
8. Johnson, L. F. 1957. Effect of antibiotics on the numbers of bacteria and fungi isolated from soil by the dilution plate method. Phytopathology 47:630-631.
9. Littman, M. L. 1947. A culture medium for the primary isolation of fungi. Science 106:109-111.
10. Maloy, O. C., and M. Alexander. 1958. The "most probable number" method for estimating populations of pathogenic organisms in the soil. Phytopathology 48:126-128.
11. Martin, J. P. 1950. Use of Acid, rose bengal and streptomycin in the plate method for estimating soil fungi. Soil Sci. 69:215-232.
12. Miller, J. H., J. E. Giddens, and A. A. Foster. 1957. A survey of the fungi of forest and cultivated soils in Georgia. Mycologia 49:779-808.
13. Miller, J. J., and N. S. Webb. 1954. Isolation of yeasts from soil with the aid of acid, rose bengal, and oxgall. Soil Sci. 77:197-204.
14. Nadakavukaren, M. J., and C. E. Horner. 1959. An alcohol agar medium selective for determining Verticillium microsclerotia in soil. Phytopathology 49:527-528.
15. Papavizas, G. C., and C. B. Davey. 1959. Isolation of Rhizoctonia solani Kuehn from naturally infested and artificially inoculated soils. Plant Disease Reptr. 43:404-410.
16. Reavill, Mary J. 1954. Effect of certain chloronitrobenzenes on germination, growth and sporulation of some fungi. Ann. Appl. Biol. 41:448-460.
17. Schneider, J. R. 1956. A selective medium for routine isolation of Graphium ulmi Schwarz. Plant Disease Reptr. 40:816-821.
18. Smith, N. R., and V. T. Dawson. 1944. The bacteriostatic action of rose bengal in media used for the plate counts of soil fungi. Soil Sci. 58:467-470.
19. Vaartaja, O. 1956. Screening fungicides for controlling damping-off of tree seedlings. Phytopathology 46:387-390.
20. Warcup, J. H. 1959. Studies on basidiomycetes in soil. Trans. Brit. Mycol. Soc. 42:45-52.

SPECIES DIFFERENTIATION OF NEMATODES THROUGH HOST REACTION IN TISSUE CULTURE. I. COMPARISONS OF MELOIDOGYNE HAPLA, MELOIDOGYNE INCOGNITA INCOGNITA, AND NACOBBUS BATATIFORMIS

M. L. Schuster and T. Sullivan

Accepted for publication June 7, 1960. Published with the approval of the Director as Paper No. 1011, Journal Series, Nebraska Agricultural Experiment Station.

The study was supported in part by NC-39 and a grant (E-2033-1) from the National Institute of Allergy and Infectious Diseases, Public Health Service.

SUMMARY

In tissue culture characteristic symptoms are induced by *Meloidogyne hapla*, *Meloidogyne incognita incognita*, and *Nacobbus batatiformis*. The differences are particularly evident with respect to stimulation or inhibition of root hairs and epidermal cells. The three species induce root galling and the symptom differences by surface-feeding or after entrance of nematodes into a common host.

During a physiological study of nematode diseases in tissue culture certain symptoms were induced by *Meloidogyne incognita incognita* (Kofoid & White) Chitwood (1). The study was continued with other rootgalling species to see if morphologic symptoms in infected plants differ with different species. We have shown (1) that *M. incognita incognita* induces galls by surface feeding; herein we report observations on gall induction by surface-feeding of three root-galling nematodes, and differentiate them by the reaction of a common tissue-culture host.

Materials and methods.—Cultures of the nematodes were obtained from plants grown in the greenhouse. *Meloidogyne hapla* Chitwood and *M. incognita incognita* were grown on tobacco (*Nicotiana tabacum* L.), and *Nacobbus batatiformis* Thorne & Schuster (4, 5) was maintained on sugar beets (*Beta vulgaris* L.). The egg sacs of the root-knot nematodes (*Meloidogyne* spp.) and Cobb's galling nematode (*N. batatiformis*) were obtained from the roots of infected plants by washing them in running tap water until they were free from soil particles. Fifty egg sacs of each root-galling nematode were sterilized and agitated 4 minutes in a test tube containing 5 ml of 10% Purex (5.25% NaOCl) (1, 3). This procedure broke up the egg sacs and surface-sterilized the eggs. The suspension of eggs was poured into a glass tube containing 50 ml of sterile distilled water. The nematode eggs that settled out in about 25 minutes were drawn off (with minimum liquid) through a tap at the bottom of the tube into 10 ml of triple-strength modified Heller's solution (1) adjusted to pH 6.5. This nutrient medium stimulated the emergence of larvae from eggs. The procedure diluted the Purex and separated the larger, heavier eggs (which give rise to larvae) from smaller eggs (which usually do not).

Individual hatched larvae were placed 3 mm from the tips of excised roots or intact roots of Kokomo variety of tomato (*Lycopersicon esculentum* Mill.) seedlings growing aseptically in Petri dishes. Each dish contained one seedling or one excised root and about 35 ml of 1% agar medium (White's minerals (7)), adjusted to pH 6, containing 1% cellobiose and 0.1m*M* ferric chelate (1). Each experiment for each nematode species consisted of 20 Petri dishes and 4 uninoculated control dishes. Tomato seeds were treated 15 minutes with 10% Purex, rinsed in sterile distilled water, and transferred to moist filter paper in Petri dishes to germinate. When the seedling root was about 3 cm. long, 1 cm of the tip was excised for tissue culture. When whole seedlings were used, the intact seedling was transferred to the artificial medium.

Results.—About 60% of the larvae infected the roots and induced the described symptoms at the site of the galls. Consistent differences in morphologic symptoms induced by the nematode species were apparent on roots either below or near the agar surface (Fig. 1). *M. incognita incognita* "prevented" root hair formation on the gall. This was more noticeable on galls near or on the agar surface. The epidermal cells of the galls tended to be square in outline; in three dimensions they would appear isodiametric. *M. hapla* induced root hair formation on subsurface galls. Root hair development was greater on galls at the agar surface than on the root surfaces adjacent to the gall. The epidermal cells were comparable in shape to the example mentioned for *M. incognita incognita*. *N. batatiformis* prevented root hair formation at the site of the gall. This nematode produced symptoms differing from symptoms produced by the species in that most of the epidermal cells of the induced galls became almost spherical. *Nacobbus* also caused necrosis, which was quite evident in the areas where they fed. The other two species were less destructive from this standpoint.

The larvae of all three species were capable of inducing gall formation by surface feeding. The symptoms as described accompanied gall formation when these larvae surface-fed or after they entered the host root.

Discussion.—Sasser (2) has shown that 5 species of Meloidogyne could be differentiated through the reaction of several plant species. Only *M. hapla* differed from 4 other species in type of galling. It would be more desirable to limit the number of plant species and save time. Our tissue-culture work shows that 2 *Meloidogyne* species and *Nacobbus batatiformis* affect the host in a characteristic manner. The procedure is much simpler and takes less time than Sasser's. It also has advantages for the biologist who is not adept at identifying root-knot nematodes by the perineal pattern technique. The hope is that the technique can differentiate other *Meloidogyne* spp. not immediately available at the time of the initial experiments. Differentiation or identification by the method

described would be facilitated by a common host for all the root-knot nematodes. Tomato is such a host for 5 species of Meloidogyne (3). Our method is offered, not as a substitute for the method based on the morphology of the adult female, but rather as supplementary. It is probable that minor differences in pathogenicity within the same species may be detected. Thus, pathogenic races may be recognized or differentiated by our method.

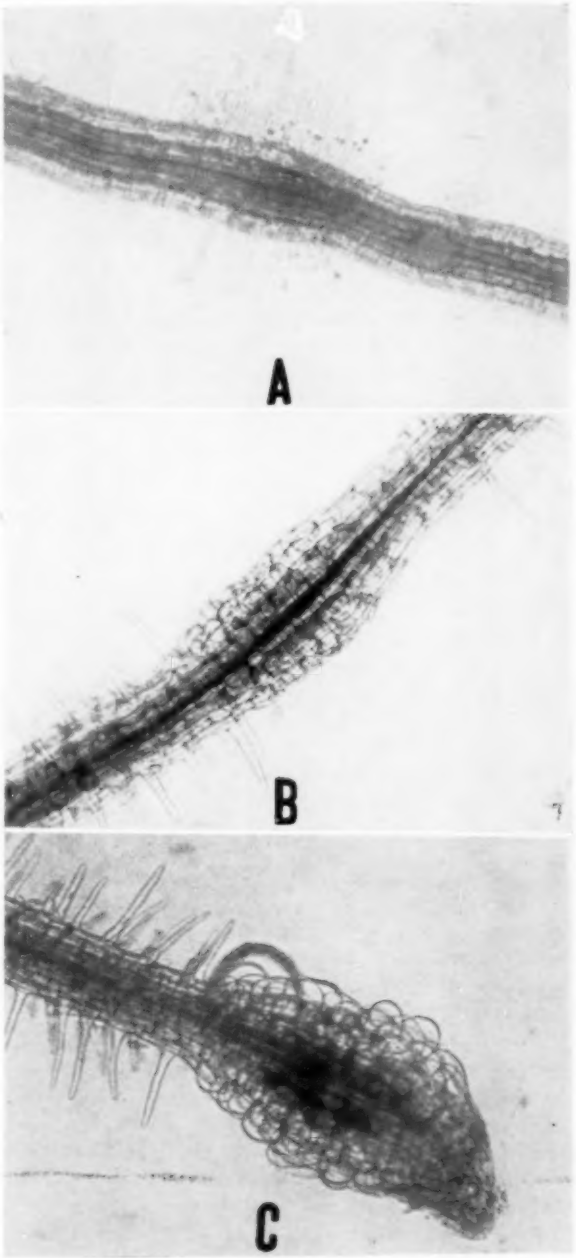


Fig. 1.—Characteristic morphologic symptoms by 3 root-galling nematodes on surface and subsurface galls in tomato roots in nutrient agar medium. **A)** *Meloidogyne hapla* galls in subsurface root. **B)** *M. incognita incognita* galls in surface root. **C)** *Nacobbus batatiformis* galls in surface root.

Another point of interest is that *M. hapla* induces or increases root hair formation and *M. incognita incognita* prevents it. *M. hapla* in soil experiments causes a proliferation of secondary roots and *M. incognita incognita* does not. With these species, root hair induction may be correlated with secondary root stimulation insofar as *M. hapla* and *M. incognita incognita* are concerned. *N. batatiformis*, however, must operate in a somewhat different fashion, for it prevents root hair formation in tissue culture and induces secondary root development in soil tests (4, 5). A relation between root hair and secondary root initiation may be invalid in light of the different sources of the two entities: a root hair is a mere extension of the exterior cell wall of an epidermal cell; and a secondary root originates from the pericycle. The inciting agent for both, however, may be similar. Plants infected with the root galling nematodes, presumably, would be differentially affected insofar as water absorption capacities are concerned depending upon species that were involved.

It has been assumed that galls are not formed until some time after the larvae of root-knot nematodes have entered the host. Tyler (6) found that root penetration by root-knot nematode larvae and gall formation in Petri-dish cultures require 4 days at 15.0°C. decreasing to 21 hours at 35.0°C. Our studies confirm previous work in our laboratory (1) on induction of gall development by surface feeding of *M. incognita incognita*, and also demonstrate that second-stage larvae of *M. hapla* and *N. batatiformis* are capable of gall induction on roots by surface feeding. This phenomenon is more common than had been realized.

The secretions given off by the three root-galling nematode species evidently differ somewhat, for they differ in the morphologic symptoms they induce. The differences in secretions may be quantitative rather than qualitative, although other symptoms make that unlikely. It has been suggested that nematode excretions are one of the agents inciting root-knot formation. That theory is not supported by the rapid development of galls with surface-feeding.

LITERATURE CITED

1. Loewenberg, J. R., T. Sullivan, and M. L. Schuster. 1960. Gall induction by Meloidogyne incognita incognita by surface feeding and factors affecting the behavior pattern of the second-stage larvae. Phytopathology 50:322-323.
2. Sasser, J. N. 1954. Identification and host-parasite relationships of certain root-knot nematodes (Meloidogyne spp.). Maryland Univ. Agr. Expt. Sta. Tech. Bull. A-77.
3. Sayre, R. M. 1958. Plant tissue culture as a tool in the study of the physiology of the root knot nematode, Meloidogyne incognita incognita (Kofoid & White) Chitwood. Ph.D. thesis. Univ. of Nebr.
4. Schuster, M. L., and G. Thorne. 1956. Distribution, relation to weeds, and histology of sugar beet root galls caused by Nacobbus batatiformis Thorne & Schuster. J. Am. Soc. Sugar Beet Technologists IX:193-197.
5. Thorne, G., and M. L. Schuster. 1956. Nacobbus batatiformis, n. sp. (Nematoda: Tylenchidae), producing galls on the roots of sugar beets and other plants. Proc.

Helminthol. Soc. Wash. D. C. 23:128-134.
6. Tyler, Jocelyn. 1933. Development of the root-knot nematode as affected by temperature. Hilgardia 7(10):391-415.
7. White, P. R. 1943. A handbook of plant tissue culture. Jacques Cattell Press, Lancaster, Pa. p. 277.

DEVELOPMENT OF WESTERN GALL RUST IN LODGEPOLE PINE

R. S. Peterson

Plant Pathologist, Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. D. A., with headquarters at Fort Collins, Colorado; in cooperation with Colorado State University.

Accepted for publication June 20, 1960.

Some of the data presented were in the author's Ph.D. thesis at the University of Michigan. The help of Michigan Professors D. V. Baxter (forestry) and E. D. Rainville (mathematics) is gratefully acknowledged.

SUMMARY

Peridermium harknessii is a damaging parasite of western pine trunks. Host cambium is stimulated to produce galls that contain more than 5 times the normal percentage of ray parenchyma. There is a high correlation between rust and host growth rate: lateral advance of the rust from the edges of trunk cankers is, on the average, about twice the host's annual radial increment. This rate is usually insufficient to girdle and kill trunks quickly, so that live rust mycelia 200 years old are not uncommon.

Anatomical studies have been reported for 4 of the dozen or so pine stem rusts native to America. Western gall rust (*Peridermium harknessii* Moore, monokaryotic stage of a *Cronartium*) has been examined in branch galls (7, 13), but not in its more important trunk cankers. These occur on several pine species, but in the Rocky Mountains are particularly abundant and damaging on lodgepole pine (*Pinus contorta* Doug. ex Loud.).

Mycelia of the *Cronartium* species on pine are similar; thus Jackson and Parker's summary description of *Cronartium fusiforme* (4) is applicable to western gall rust, except that the latter penetrates tracheids and goes deep into the xylem, and its galls are not usually spindle-shaped. Differences in hyphal diameters reported for various species may be significant, but should be checked by a single worker using one method of measurement. If truly different, the hyphae of *C. ribicola*, *C. occidentale*, and *C. comptoniae* would constitute the "large" class—about 5 μ diameter in wood rays (1, 2). *C. fusiforme* is in a "middle" group—about 3.5 μ (4)—and *Peridermium giganteum* is shown to have hyphae less than 2 μ in diameter (10).

Growth characteristics of the pine rusts vary greatly by species. *P. filamentosum* is said to be systemic and capable of spreading about 40 cm per year vertically in trunks (8). Fusiform rust cankers on slash pine trunks elongate about 13 cm per year (12). *P. stalactiforme* on lodgepole about 18 cm per year (9), and *C. ribicola* on western white pine 5–20 cm per year, the lower values on branches and the higher on trunks (6). Lateral growth is 0.6–1.2 cm per year for *P. stalactiforme*, which seldom girdles its hosts (9), and 6–9 cm for *C. ribicola*, which consistently girdles (6). There has been little emphasis on the relation of rust growth to host tree growth, and in fact for one fir stem rust, Roth (11) reported that no such relationship exists. Lachmund (6) found for *C. ribicola* that growth seems to be only occasionally related to host vigor.

Techniques.—Blocks from rust cankers in lodgepole pine were cut during the spring and summer of 1958. Infested tissue was fixed in formalin-acetic acid, sectioned freehand or with a sliding microtome, and stained with orseillin and aniline blue according to Jewell's schedule (5). About 120 slides prepared in this manner were examined. Measurements of hyphae, haustoria, and host cells were checked in fresh water mounts and in chromic-acetic fixed specimens, where they proved similar to those in FAA preparations.

Rust growth was studied by means of ring measurements in sections sawed from the centers of cankers (Fig. 1). Sections were cut in the main plane of fungus growth. Widths of rings and distances to the pith were taken to the nearest 0.1 mm. Central angles subtended by the canker were measured to the nearest 1°, 0.5°, or 0.1°, depending on annual change of angle. Cankers were not selected randomly, but specifically to include representative numbers of slow- and fast-growing trunks. Most specimens were collected in northern Colorado; a few were from Wyoming, Montana, and Washington.

Fungus morphology.—Rust mycelium is abundant in all living host tissues near the center of a canker, including the wood rays extending inward through many annual rings. Hyphae vary from 1.5 to 4.5 μ in diameter, with occasional short cells as much as 7 μ wide. In xylem rays, where most measurements for related rusts have been made, hyphae are 3–4 μ in diameter, putting this rust in the "middle" group with regard to size. Hyphal cell length is extremely variable: in rays it is usually 20–40 μ.

In tangential section most wood rays exhibit more radially oriented rust hyphae than ray cells. Relatively few hyphae leave the rays in traversing the xylem. Most tracheids are penetrated by haustoria where the fibers come in contact with hyphae in rays, but the fungus in these dead cells forms small, rounded haustoria that may not be functional (Fig. 2-A), though some contain cytoplasm and a nucleus. Haustoria in dead cells often appear to be coated with a layer of yellow material (yellow in stained or unstained preparations) that appears continuous with the cells' secondary walls. Haustoria in tracheids are seldom over 12 μ in their largest dimension.

Haustoria in living cells generally become 10–25 μ

long and 4–6 μ wide (Fig. 2-B). No branched haustoria were noted. Both haustoria and hyphal cells have single nuclei, which (when stained red with orseillin) appear to be about 1.0–1.5 $\times$ 1.5–2.5 μ.

Host anatomy.—The pronounced host reaction to rust invasion is hyperplasia. Cells produced by a rust-infected cambium are scarcely larger, except in the rays, than corresponding types in healthy stems, but they are more abundant. Comparison of the average widths of the infected and uninfected portions of 50 annual rings in cross sections from 5 cankers yielded the following:

Fig. 1.—Cross sections of rust cankers in lodgepole pine 3–12 in. in diameter. The original site of infection, a branch gall, is still attached in the smallest specimen.

1) Total thickness of the 50 uninfected rings was 6.6 cm and of the infected 15.5 cm; the ratio is 1:2.3.
2) This ratio is lowest where the normal ring width is greatest, and vice versa; that is, fast normal growth is least accelerated by the rust, and slow growth is more accelerated.

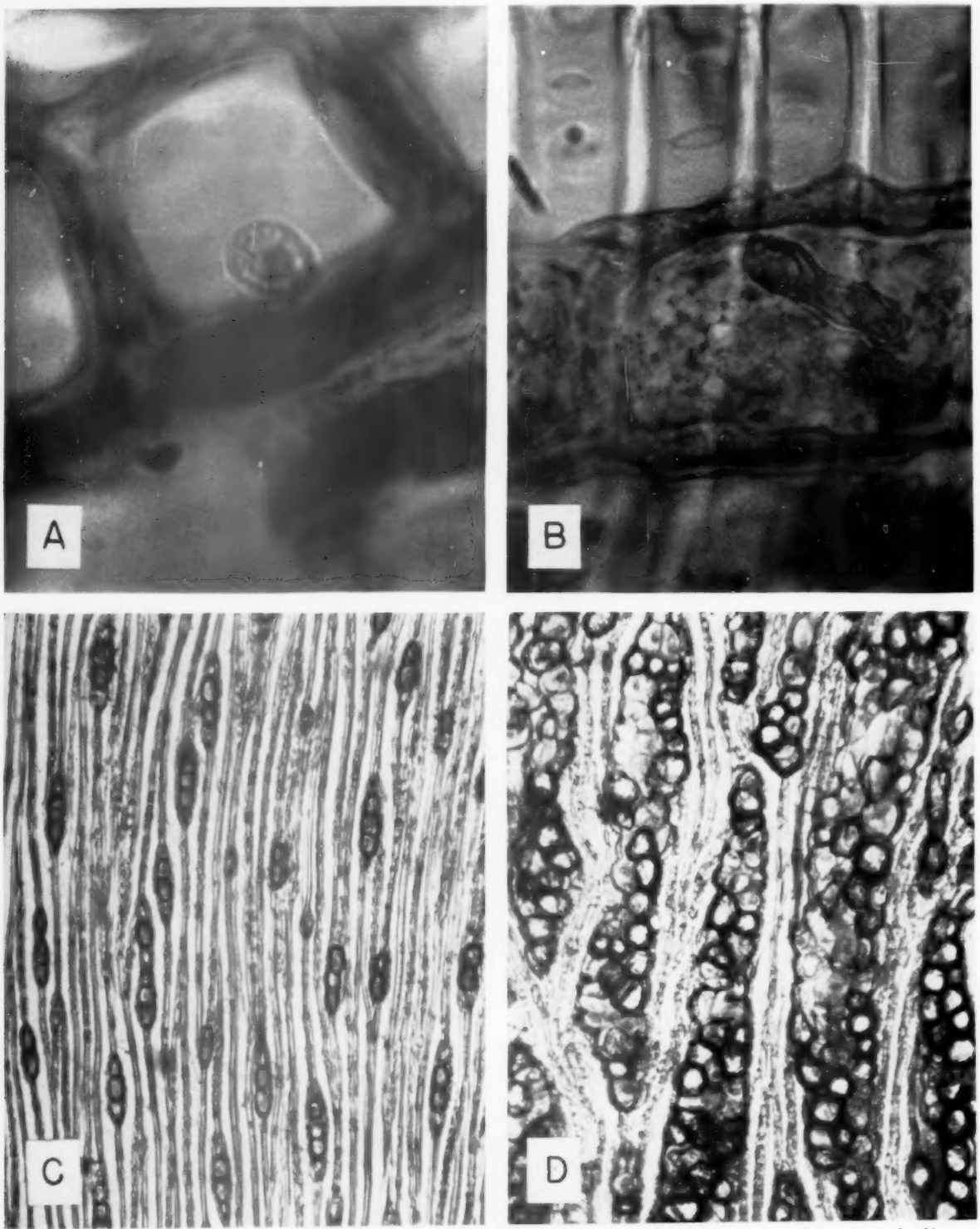


Fig. 2.—**A)** Abortive haustorium in a tracheid. Transverse; ×1800. **B)** Normal haustorium in xylem ray, and adjacent hyphae. Radial; ×1200. **C)** Healthy wood. Tangential; ×140. **D)** Rust-infected wood in the same growth ring as (C). Tangential; ×140.

Not only are more cells produced in rust-infected wood, but cell types are produced in different proportions than in normal wood (Fig. 2-C,D). A count of 1100 cells along tangential lines in 9 cross sections from young cankers indicated that 29% of the cells were ray parenchyma. (Lowest percentage in a section was 26.3; highest, 30.3.) Similar counting of 1300 cells in rust-free wood showed only 8% to be parenchymatous. (Lowest percentage in a section was 5.8; highest, 12.5.) In a sample of 200 xylem parenchyma cells, average tangential width was 22.2 μ in cankers and 12.9 μ in uninfected wood. Average tracheid widths, on the basis of 450 cells measured, differed only slightly; 19.6 μ in cankers and 17.6 μ in normal tissue. (These figures are smaller than comparable data from older stems; for instance, lodgepole tracheids usually become 23–40 μ in diameter.)

From the above data it is possible to approximate the relative volumes of tracheids and parenchyma, if intercellular spaces are ignored. Rust-infected wood appears on this basis to consist of 32% parenchyma and 68% tracheids, and normal wood of 6% parenchyma and 94% tracheids.

On the basis of examination of 40 sq mm of tangential sections, about 60% of the xylem rays in cankers were found to be biseriate or multiseriate. In rust-free wood only the infrequent resin-conducting rays (fewer than 2% of the total) are more than one cell wide. There is some disarrangement of tracheids in infected wood: that is, the products of a given cambial initial are in some instances difficult to identify. Walls in individual tracheids are apt to be sinuous and variable in thickness, averaging a little thicker than in normal wood. But the tissue appears to be efficient for conduction, inasmuch as radial and tangential pits are somewhat more abundant than in rust-free xylem, and there are pits on the rather blunt end walls.

Most wood formed by rust-infected cambium quickly darkens, becoming yellow-brown to chocolate-brown. This is largely due to deposition of resin—a process described long ago for *Peridermium pini* cankers (3). The resinous wood is resistant to decay; thus old cankers and galls may be found in forest litter, outlasting the trees that bore them. A practical result is that gall rust cankers, although themselves causing cull in pine trunks, seldom add to this damage by serving as entrance points for decay fungi.

The discolored wood is at first soft and wet, but finally exceptionally hard, dulling axes or saws used to cut it. The mechanical strength of the trunk at a canker remains low, and large numbers of cankered trees are broken by wind.

In canker phloem both hypertrophy and hyperplasia are apparent. However, greater than normal pressure on the older phloem results in little or no net increase in volume of the whole tissue. Increased percentage of parenchyma is probably as marked as in xylem, but exact figures could not be obtained because identifying crushed elements of the phloem was difficult.

In rust-infected cortex there is some hypertrophy and necrosis, but no notable hyperplasia. Cortical and phloem cells are sloughed off when the rust forms fruiting bodies within these tissues; eventually the progressively deeper-forming fruiting bodies expose and thus kill the cambium. During most of the life

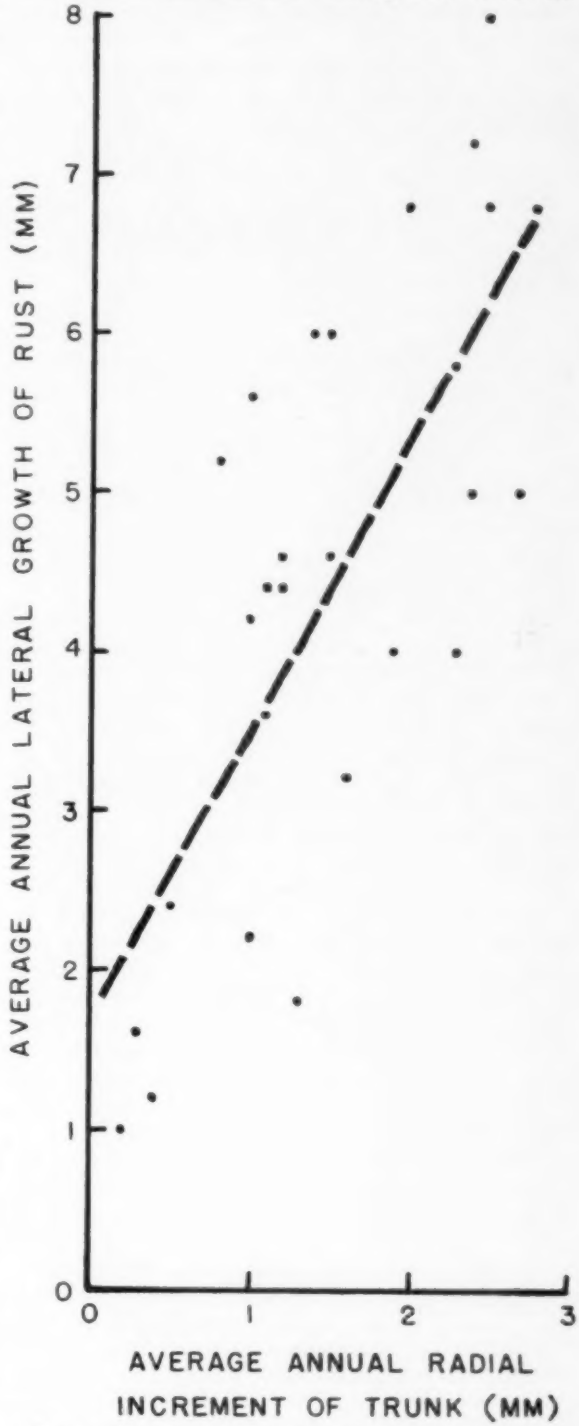


Fig. 3.—Relation of gall rust's lateral spread from canker edges to radial growth of the host. The points represent average measurements for 760 annual rings in 27 cankers.

of a canker, exposure of cambium in this manner merely results in death of one secondary gall and formation of a new one; finally, however, the ring of secondary galls encircles the trunk and kills the tree.

Rust growth.—The lateral, or girdling, growth rate of gall rust on trunks is related to the host's radial increment; the correlation coefficient for the data in Fig. 3 is 0.740. Each of the 27 points in this figure represents the average annual growth of rust and host for one canker; they are based on measurements of radial increment and rust spread in 760 annual rings. The linear regression is $g = 1.7 + 1.8\ r$, in which g is lateral advance of the rust around the trunk, r is radial increment of the tree near canker height, and all measurements are from the cambium in millimeters. More accurate for low values of r would be $g = r^2 + 2$ or $g = 0.1(1.6r)^3 + 2$—that is, functions that are relatively flat near the origin—but acceptance of these curves is not justified without a greater range of data.

The straight-line formula may be converted to give the approximate number of years, n, required for gall rust to girdle a trunk of initial radius R and annual increment r:

$$n = \left(1 + \frac{R}{r}\right)\left(e^{\frac{6.28r}{1.7 + 1.8r}} - 1\right)$$

in which e is the base of natural logarithms. An example for calculation would be a trunk 50 mm in radius, newly infected from a branch gall, with annual increment of 2.5 mm; the tree will probably not be girdled for about 243 years $[(1 + 20)(e^{2.532} - 1)]$. If the trunk were only 10 mm in radius, encirclement would be expected in about 58 years.

Where there is already a canker present and it is desired to estimate years before girdling, the central angle (in radians) subtended by the initial canker in a cross section of the trunk should be subtracted from 6.28 in the above formula. Thus, a trunk of 50 mm radius, already half-encircled by the rust and growing at 2.5 mm per year, might be girdled in about 53 years.

Vertical growth of gall rust is ordinarily less than the horizontal growth in trunks. The greatest canker elongation measured was 1 cm per year downward for 20 years. Many cankers spread laterally for decades with no appreciable vertical growth.

Discussion.—With present knowledge it would be impossible to distinguish among pine stem rusts on the basis of vegetative morphology; western gall rust is closely similar to the other species reported. Pathological anatomy of *P. harknessii* hosts, too, is similar to that of trees infected by other gall rusts. On the other hand it seems possible in many instances to identify the species causing a rust canker merely by noting the ratio of length to width of the canker, and the presence or absence of xylem hyperplasia. *Peridermium harknessii*, unlike most species, usually grows faster around the stem axis than along it. *Cronartium ribicola* cankers, however, are said to be wider than high during their first few weeks (6), and *C. quercuum* cankers are like those of western gall rust in shape.

It might be expected that the more vigorous a tree, the faster its obligate parasites would grow. For tree rusts this relationship has not been found to hold (6, 11). The present study, though it presents no causal explanation, does provide evidence for a high correlation between selected dimensions of growth of the rust and its host.

The growth formulae do not allow us to generalize about tree mortality that will result from a given rust outbreak, because the fungus invades trunks in different ways and because annual increment is not actually constant. Infection on a young stem leader will result in early girdling—perhaps in 3 or 4 years. Older trunks are not infected directly (except in wounds), but new branches are attacked and the rust may enter large trunks from the branches. Thus, from a given year's outbreak, all sizes of stem will eventually be cankered and canker growth must be predicted on an individual basis rather than for whole stands.

It is possible, however, to surmise from these formulae that gall rust, because of its slow development, is not likely to be a major cause of mortality in large-diameter stems. And, in fact, because it doesn't destroy its host quickly (unlike white pine blister rust) it is among the longest-lived of parasitic fungi. One mycelium examined had only two-thirds girdled a lodgepole pine between 1743 and 1957; another was at least 277 years old and still growing. Unfortunately, this slow growth is a greater problem in forest management than quick killing would be, because the cankered trees continue to occupy growing space but may produce little wood of value.—Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

LITERATURE CITED

1. Adams, J. F. 1919. Sexual fusions and development of the sexual organs in the Peridermiums. Penna. State Coll. Agr. Expt. Sta. Bull. 160:31-77.

2. Colley, R. H., C. Hartley, and Minnie W. Taylor. 1927. A morphologic and biometric comparison of Cronartium ribicola and Cronartium occidentale in the aecial stage. J. Agr. Research 34:511-531.

3. Hartig, R. 1882. Lehrbuch der Baumkrankheiten. Julius Springer, Berlin. 198 p.

4. Jackson, L. W. R., and J. N. Parker. 1958. Anatomy of fusiform rust galls on loblolly pine. Phytopathology 48: 637-640.

5. Jewell, F. F. 1958. Stain technique for rapid diagnosis of rust in southern pines. Forest Sci. 4:42-44.

6. Lachmund, H. G. 1934. Growth and injurious effects of Cronartium ribicola cankers on Pinus monticola. J. Agr. Research 48:475-503.

7. Lorbeer, J. W. 1955. Several aspects of the pathology of Peridermium harknessii Moore. Master's thesis, Univ. of Washington. 61 p.

8. Mielke, J. L. 1952. The rust fungus Cronartium filamentosum in Rocky Mountain ponderosa pine. J. Forestry 50:365-373.

9. Mielke, J. L. 1956. The rust fungus (Cronartium stalactiforme) in lodgepole pine. J. Forestry 54:518-521.

10. Nakamura, K., and K. Mitsuhashi. 1953. Anatomical characters of gall-wood caused by Cronartium quercuum on "Akamatsu" (Pinus densiflora). Bull. Fac. Agr., Tokyo Univ. Agr. & Tech. 1:11-17.

11. Roth, C. 1955. Die Wachstum geschwindigkeit von

Weisstannenkropfen. Schweiz. Z. Forstw. 106(11):657-665.
12. Siggers, P. V. 1955. Control of the fusiform rust of southern pines. J. Forestry 53:442-446.
13. True, R. P. 1938. Gall development on Pinus sylvestris attacked by the Woodgate Peridermium, and morphology of the parasite. Phytopathology 28: 24-49.

SPECIALIZATION AMONG GREENBUGS IN THE TRANSMISSION OF BARLEY YELLOW DWARF VIRUS

W. F. Rochow

Plant Pathologist, Crops Research Division, ARS, U.S.D.A., and Associate Professor, Cornell University. I am grateful to H. H. Luke, A. N. Tissot, D. C. Arny, and Henry Jedlinski for supplying aphids or virus cultures; I am particularly indebted to H. B. Boudreaux and A. N. Tissot for careful examination of the greenbugs.

Cooperative investigation of Crops Research Division, ARS, U.S.D.A., and Cornell University Agricultural Experiment Station; supported in part by a PHS research grant, E-2540, from the National Institutes of Health.

Accepted for publication June 27, 1960.

SUMMARY

Collections of greenbugs (*Toxoptera graminum* (Rond.)) from Florida, Wisconsin, and Illinois were compared as vectors of several isolates of barley yellow dwarf virus. In 14 direct comparisons involving a virus isolate originally recovered by greenbugs from a field sample, greenbugs from Florida transmitted only once (to 1 of 92 plants), those from Wisconsin transmitted in 12 of the 14 trials (to 49 of 90 plants), and those from Illinois transmitted 12 times (to 59 of 87 plants). Greenbugs from Florida transmitted none of 3 other virus isolates used in direct comparisons, but those from Wisconsin and from Illinois readily transmitted 1 of these isolates and occasionally transmitted a second. Greenbugs from Florida transmitted virus to only 1 of 144 plants used in 44 additional tests of virus transmission by this collection. These data are considered evidence of physiological specialization among greenbugs in the transmission of barley yellow dwarf virus.

Entomologists found no morphological differences among the 3 aphid collections except that greenbugs from Florida had a beak tip slightly different from that of the other 2 collections.

Introduction.—The greenbug (*Toxoptera graminum* (Rond.); or *Schizaphis graminum* (Rond.), according to some workers) is one of several aphid vectors used in this laboratory to test field samples for suspected infection by barley yellow dwarf virus (BYDV). Oswald and Houston (6) found this species to be a vector of the virus. BYDV was recovered by greenbugs from only 2 of 160 field samples tested at Cornell in 1959 (10). This almost complete failure of greenbugs to recover the virus was surprising, since some of the samples had been collected in Illinois and in Wisconsin, where Jedlinski and Brown (4) and Arny (personal communication), respectively, had readily recovered BYDV from similar samples by means of greenbugs. A possible explanation for such differences was that the greenbug strains in use in the different laboratories varied in their ability to transmit BYDV. Clones of aphids of other species are known to differ in their ability to transmit some plant viruses (1, 11, 12, 13). Moreover, since collections of greenbugs may vary in the damage they cause on certain small grains (3), there is evidence for a kind of physiological specialization among greenbugs.

Comparisons of the ability of 3 greenbug collections to transmit BYDV are presented here.

Materials and methods.—The first greenbug collection was sent from Gainesville, Florida, by H. H. Luke and A. N. Tissot. Colonies derived from this collection had been used in the tests made during the summer of 1959 (10). The second greenbug collection was sent by D. C. Arny, from Madison, Wisconsin, and the third by Henry Jedlinski, from Urbana, Illinois. These respective collections are herein referred to as greenbugs from Florida, Wisconsin, and Illinois.

All stock colonies of virus-free aphids were maintained on caged barley plants (*Hordeum vulgare* L.) under 4 precautions described previously (9). New colonies were started weekly from newly emerged nymphs. Although all aphids maintained in this way have remained free of BYDV, some aphids from each colony used were always tested as controls.

Four isolates of BYDV were used. In most tests the isolate was one supplied by Henry Jedlinski; it is herein called the Ill-GB isolate since it was recovered from a field sample in Illinois by means of greenbugs (4). A second virus isolate (AGV) is regularly transmitted by apple grain (AG) aphids (*Rhopalosiphum fitchii* (Sand.); or *R. padi* (L.), according to some workers) but not by English grain (EG) aphids (*Macrosiphum granarium* (Kirby)). The third isolate (EGV) is regularly transmitted by EG aphids but not by AG aphids. These 2 isolates were previously described as AGV-1 and EGV-1 (9). A fourth isolate (CLV) was recovered from a New York field sample in 1959 by means of corn leaf (CL) aphids (*Rhopalosiphum maidis* (Fitch)) but not by AG or EG aphids or by greenbugs from Florida (10). It is regularly transmitted by CL aphids but not by AG or EG aphids. All virus isolates were maintained by serial transfer in oats (*Avena sativa* L.) of the variety California Red (C.I. 1026). (C.I. refers to the accession number of the Cereal Crops Research Branch, Crops Research Division.)

Acquisition feedings of 1–2 days were usually on detached leaves incubated at 15°C as described previously (7, 9). Single leaves were cut into 3 sections so that each comparison of the 3 greenbug collections was based on transmission from portions of the same leaf. Acquisition feedings longer than 2 days were on separate intact source plants caged in the greenhouse. At the end of an acquisition feeding period, aphids in groups of about 10 per plant were transferred by

Table 1.—Comparison of greenbugs from Florida, Wisconsin, and Illinois for ability to transmit 4 isolates of barley yellow dwarf virus.

Virus isolate[b]	Acquisition feeding[c] (days)	No. test plants infected in tests with greenbugs from source indicated[a]		
		Fla.	Wisc.	Ill.
Ill-GB	1–2	0/39	15/33	17/33
Ill-GB	3–6	1/53	34/57	42/54
AGV	2	0/12	7/12	10/12
AGV	6	0/6	6/6	6/6
EGV	2	0/12	0/12	0/12
EGV	6	0/6	0/6	0/6
CLV	2	0/12	2/12	1/12

[a] Numerator is number of oat test seedlings that became infected; denominator is number of seedlings infested with about 10 aphids each for a 3-day inoculation test feeding.

[b] The Ill-GB isolate was originally recovered from a field sample by greenbugs in Illinois. AGV, EGV, and CLV are regularly transmitted respectively by apple grain, English grain, or corn leaf aphids, but not by the other 2 aphid species.

[c] Acquisition feeding of 1–2 days was on detached leaves cut into 3 pieces; that of 3–6 days was on intact plants.

means of a camel's-hair brush to seedlings of California Red oats. Most of the aphids in each group were late-instar apterous females, but other stages were often included in each group. Inoculation test feedings were 3 days on caged seedlings. At the end of this 3-day period, aphids were killed by fumigation with lindane in a closed chamber. The plants were then placed on a bench under supplemental illumination in a greenhouse fumigated regularly to control insects. They were examined frequently for at least 4 weeks.

Results.—Ten direct comparisons were made among the 3 collections of greenbugs in the transmission of the Ill-GB isolate from detached leaves. Greenbugs from Florida did not transmit in any of these tests, whereas those from Wisconsin and from Illinois transmitted in all but 2 (Table 1). None of the aphid-control plants in the 10 tests became infected.

Similar direct comparisons were made after acquisition feedings of 3–6 days on intact plants infected by the Ill-GB isolate of BYDV. Greenbugs from Florida transmitted virus to only 1 of 53 plants, whereas those from Wisconsin transmitted the virus in each of 4 trials to a high percentage of the test plants (Table 1). No control plants became infected. It is clear that the collections of greenbugs differ markedly in their ability to transmit the Ill-GB isolate of the virus.

Additional comparisons involved the 3 greenbug collections in tests with 3 other isolates of BYDV. The EGV isolate was not transmitted in 4 trials by any of the greenbugs (Table 1). Greenbugs from Wisconsin and from Illinois were efficient vectors of the AGV isolate in each of 4 tests, but those from Florida did not transmit AGV to any of 18 plants in 4 trials (Table 1). Greenbugs from these same 2 locations also transmitted the CLV isolate occasionally, but those from Florida did not transmit this isolate in any of 3 attempts (Table 1). None of the aphid-control plants in these tests became infected. Thus greenbugs from Florida failed to transmit 3 different isolates of BYDV that were transmitted by the other 2 collections.

In addition to the direct comparisons of the 3 greenbugs (Table 1), 44 other attempts were made over about 8 months to transmit various isolates of BYDV by means of greenbugs from Florida. These trials, which involved about 1440 greenbugs, were

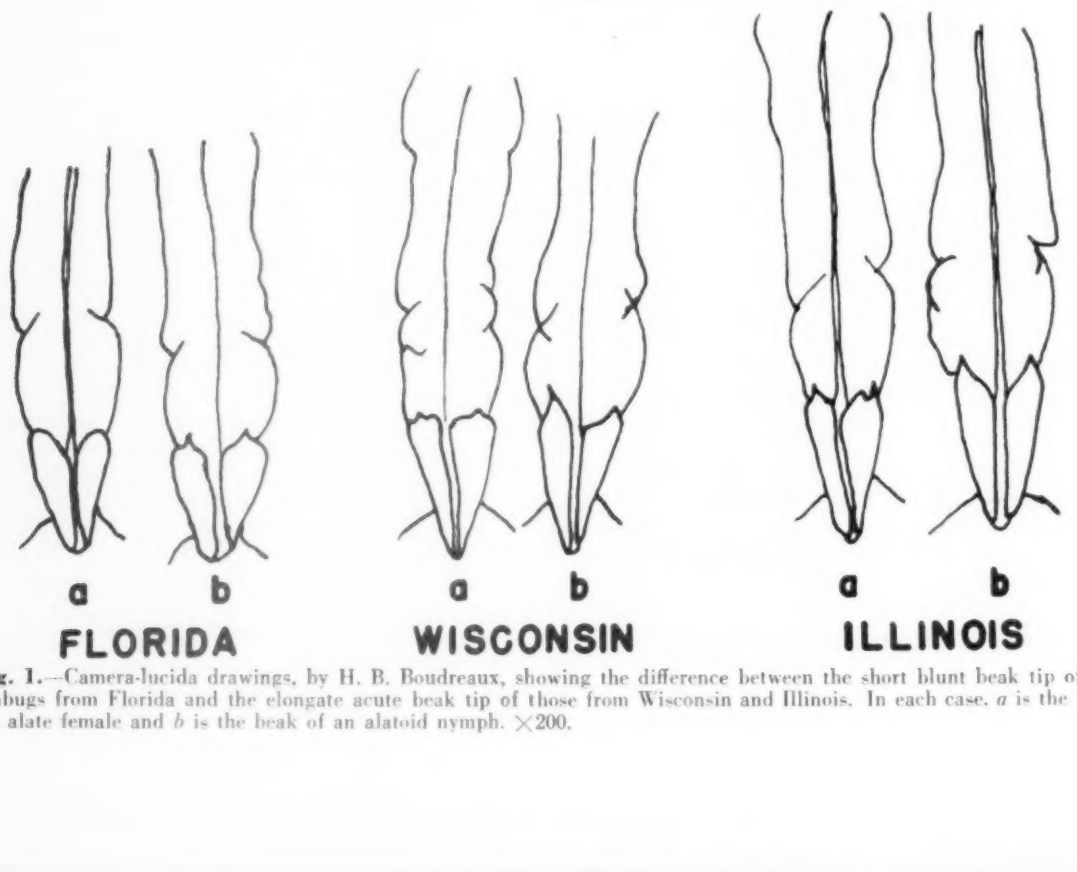


Fig. 1.—Camera-lucida drawings, by H. B. Boudreaux, showing the difference between the short blunt beak tip of the greenbugs from Florida and the elongate acute beak tip of those from Wisconsin and Illinois. In each case, *a* is the beak of an alate female and *b* is the beak of an alatoid nymph. ×200.

made with 144 test plants. Only 1 of 144 plants became infected, the exception being in a test using the Ill-GB isolate. Thus, greenbugs from Florida have transmitted virus in this laboratory to 2 plants of 284 used in all kinds of tests. For all practical purposes the greenbugs from Florida did not transmit BYDV since one can never be sure of complete absence of contamination in work of this kind, and since the low level of transmission by Florida greenbugs is in such contrast to that of the other 2 greenbug collections.

Specimens of each of the 3 greenbugs were kindly examined by H. B. Boudreaux (Louisiana State University) and by A. N. Tissot (University of Florida). Both workers confirmed identification of the aphids and examined the 3 kinds for any possible morphological differences. No morphological differences were found except for a detail of the tip of the beak. Greenbugs from Wisconsin and from Illinois had a beak whose tip (rostral segments IV and V) had an elongate acute appearance; those from Florida, however, had a rostral tip more nearly typical of many of the grass-feeding species, having somewhat curved sides and being blunter and shorter than those of the other 2 collections (Fig. 1). These differences were consistent in all specimens examined from 6 separate colonies of each greenbug taken at intervals over a period of 6 months.

The transmission experiments reported here also provide additional data on the relative vector specificity of some isolates of BYDV. In a previous comparison of AGV and EGV, EGV was found to be more vector specific than was AGV with respect to transmission by AG and EG aphids (9). This same relationship holds in regard to transmission by greenbugs: none of the greenbugs transmitted EGV although 2 of the collections readily transmitted AGV.

Seven comparative transmission experiments were made with the Ill-GB isolate of BYDV by means of AG, EG, and CL aphids to investigate the vector relationships of this virus isolate. All aphid-control plants remained healthy. AG aphids transmitted Ill-GB in all 7 attempts (to 25 of 27 plants), EG aphids transmitted in 5 of 7 attempts (to 16 of 27 plants), but CL aphids failed in all 7 attempts (to 0 of 24 plants). The Ill-GB virus isolate appears to be similar to AGV, since each is transmitted readily by AG aphids and by greenbugs, occasionally by EG aphids, and very rarely, if at all, by CL aphids.

Discussion.—The main point is the demonstration that, in work with BYDV, consideration should be given to a new variable: specialization among collections of an aphid vector. Several kinds of variation among isolates of the virus are known; it is not surprising that variation should also be found among collections of a vector. Similar variation may exist among collections of other aphids known to be vectors of BYDV, but differences as striking as those found for greenbugs apparently have not been encountered. Previous comparisons of 4 different AG aphid collections (7, 8) and cooperative tests with Bruehl (2) have failed to reveal any such differences among AG aphids; different forms of the AG aphid collected from winter hosts in nature, however, have been found to vary as vectors of the virus (5).

The difference between the greenbugs from Florida and those from the Midwest is particularly striking because it is virtually absolute as regards the tests reported here. Since only a single greenbug collection had been received from each area, it is obvious that the colonies used here do not necessarily represent the strains of greenbug common in these areas. The important thing is that collections of greenbugs can vary in their ability to transmit BYDV. There is no reason why similar variability could not be important in nature.

Correlation of the structure of the beak with ability to transmit virus is an interesting development of this work. It remains to be seen, however, whether the morphological difference in beak structure has any direct connection with the physiological difference in virus transmission.

Since the BYDV disease is still fairly new, confirmation of diagnosis poses a problem for many workers. Information is now available on some of the factors that must be considered in any attempt to confirm diagnosis by recovering the virus from field samples. First, the general suggestion of Stubbs (12) on possible importance of "inactive" insects in any collection used in virus transmission studies now has a basis in work on BYDV, at least for one of the vectors. Second, the variability among isolates of the virus, particularly as regards vector specificity, is a factor that must be considered (10). In other words, if one fails to recover virus from a plant thought to be infected by BYDV, the problem of whether the proper aphid species and/or the proper clone of the aphid was used complicates interpretation of the negative results.—Department of Plant Pathology, Cornell University, Ithaca, New York.

LITERATURE CITED

1. Björling, K., and F. Ossiannilsson. 1958. Investigations on individual variations in the virus-transmitting ability of different aphid species. Socker Handl. H 14: 1-13.

2. Bruehl, G. W. 1958. Comparison of eastern and western aphids in the transmission of barley yellow dwarf virus. Plant Disease Reptr. 42:909-911.

3. Dahms, R. G. 1948. Comparative tolerance of small grains to greenbugs from Oklahoma and Mississippi. J. Econ. Entom. 41:825-826.

4. Jedlinski, H., and C. M. Brown. 1959. Barley yellow dwarf virus on oats in Illinois in 1959. Plant Disease Reptr. Suppl. 262:326-332.

5. Orlob, G. B., and D. C. Arny. 1960. Transmission of barley yellow dwarf virus by different forms of the apple grain aphid, Rhopalosiphum fitchii (Sand.). Virology 10: 273-274.

6. Oswald, J. W., and B. R. Houston. 1952. The greenbug, Toxoptera graminum Rond., a vector of the cereal yellow-dwarf virus. Plant Disease Reptr. 36:182-183.

7. Rochow, W. F. 1958. Barley yellow dwarf virus disease of oats in New York. Plant Disease Reptr. 42:36-41.

8. Rochow, W. F. 1958. The role of aphids in vector specificity of barley yellow dwarf virus. Plant Disease Reptr. 42:905-908.

9. Rochow, W. F. 1959. Transmission of strains of

barley yellow dwarf virus by two aphid species. Phytopathology 49:744-748.

10. Rochow, W. F. 1959. Differential transmission of barley yellow dwarf virus from field samples by four aphid species. Plant Disease Reptr. Suppl. 262: 356-359.

11. Simons, J. N. 1959. Variation in efficiency of aphid transmission of southern cucumber mosaic virus and potato virus Y in pepper. Virology 9: 612-623.

12. Stubbs, L. L. 1955. Strains of Myzus persicae (Sulz.) active and inactive with respect to virus transmission. Australian J. Biol. Sci. 8:68-74.

13. Williams, W. L., and A. F. Ross. 1957. Aphid transmission of potato leafroll virus as affected by the feeding of nonviruliferous aphids on the test plants and by vector variability. (Abstr.) Phytopathology 47:538.

SOME EFFECTS OF 8-AZAGUANINE ON TOBACCO MOSAIC VIRUS REPLICATION

R. C. Lindner, P. C. Cheo, H. C. Kirkpatrick and H. C. Govindu

Respective addresses of second and fourth authors: California Institute of Technology, and University of Mysore, Bangalore, India.

Accepted for publication June 27, 1960. Scientific Paper No. 1930, Washington Agricultural Experiment Stations, Pullman, Washington. Project No. 1244.

These studies were supported in part by funds provided for biological and medical research by the State of Washington Initiative Measure No. 171.

SUMMARY

The *Physalis floridana*-TMV (tobacco mosaic virus) system was very responsive to 8-azaguanine. Treatment inhibited virus replication sites and resulted in virus that varied in infectivity, sedimentation time, and nucleic acid content. Systemic virus spread was inhibited much more than could be accounted for by inhibition of replication sites. Virus isolates from treated plants contained modified virus. On centrifugation, the infective fraction (V_t) sedimented more slowly than normal TMV (V), and the uninfective fraction (V_m) sedimented more slowly than V_t. Inhibition in total virus titer and the ratio of V_m/V_t were parallel and were functions of time of application and concentration of 8-azaguanine. V_m increased to a maximum in about 2 weeks and then declined. V_m reverted to V_t *in vivo;* the reversion was a function of the 8-azaguanine concentration in the tissue and the temperature. The ratio of V_m/V_t was independent of virus inoculum titer. There was no direct effect of 8-azaguanine on TMV, but the action was governed by the host. Tobacco was much less responsive than *P. floridana*. There was no inhibition of virus replication sites in tobacco, contrasted to as high as 99% initial site inhibition in *P. floridana* and a 32% inhibition of total sites. In local-lesion hosts, 8-azaguanine inhibited lesion numbers in cucumber and *Nicotiana glutinosa* but not in *N. tabacum* var. NN. V_t increased as such when used as inoculum and was more susceptible to 8-azaguanine treatment than V. V_m did not interfere with local lesion counts of V. Attempts to isolate V_m from V_t by electrophoresis or chromatography were unsuccessful. Infective RNA was isolated from V and V_t, and the infectivity was 4/5 less for V_t RNA at concentrations where whole virus of the two isolates was equally infective. The mechanism of 8-azaguanine action was best explained by assuming that it was incorporated in the virus replication sites in the host in varying amounts, resulting in the production of virus with varying amounts of incorporated 8-azaguanine. A low order of substitution in the replication site would yield infective virus (V_t), a moderate order would yield uninfective virus (V_m), and a high order would completely block virus replication. The effect of 8-azaguanine in inhibiting systemic virus spread may be owing to some other mechanism.

Introduction.—The guanine analog 8-azaguanine inhibits the multiplication of a number of plant viruses, including virus tumors of Rumex (15), alfalfa mosaic (7), cucumber mosaic (7), tobacco mosaic (8), stone fruit ringspot (4), turnip yellow mosaic (13), and sugar beet yellows (17). It is reported to be ineffective against the viruses of henbane mosaic, potato X, potato Y, spotted wilt, tropaeolum II, and pea mosaic (9). In a series of studies on the effect of 8-azaguanine on viruses, Matthews (7–13) showed that this purine analog was substituted into the virus for guanine, and the inhibitory effects on virus replication were related to the substitution. This work has been reviewed by Matthews and Smith (14). The present report concerns studies toward further elucidation of the mechanism of action of 8-azaguanine.

Materials and methods.—A common strain of TMV (tobacco mosaic virus) was purified from infected *Physalis floridana* Rydb. leaves by repeated differential centrifugation of a heated clarified leaf homogenate (18). This stock solution, maintained at 4°C in a concentrated form, was used in appropriate dilutions for the work reported here. Inoculations were made with a cloth pad saturated with inoculum containing 5% by weight of carborundum (6).

P. floridana was the most commonly used host. Plants grown in 2½-in. pots were pruned to a single leaf to avoid systemic effects. *Nicotiana tabacum* L. var. Turkish was also used and pruned to a single leaf. Some trials were conducted with the local-lesion hosts *Cucumis sativus* L. var. Chicago Pickling, *N. glutinosa* L., and *N. tabacum* L. var. NN. Where studies on systemic virus spread were made, *P. floridana* plants were pruned to 2 leaves.

8-azaguanine was dissolved in 0.1% sodium carbonate plus 0.1% Aerosol O.T. and applied with a soft brush. Controls were painted with 0.1% sodium carbonate in 0.1% Aerosol O.T.

Leaf samples for virus purification were frozen and homogenized in buffer (5), and the virus was purified from the heat-clarified homogenate by repeated differential centrifugation (18). Virus concentration was then determined spectrophotometrically (20).

Cucumber cotyledons were used for infectivity assays. In preliminary trials, the infectivity of TMV isolates from 8-azaguanine-treated plants was similar on bean, *Phaseolus vulgaris* L. var. Pinto, and cucumber, but cucumber was used as the assay host because it was available from other studies. The infectivities

of various isolates were always compared against the standard isolate on paired cotyledons with methods previously outlined (6). Dilutions were based on spectrophotometric assays of purified isolates. Isolates from untreated *P. floridana* plants always had infectivities similar to that of the control isolate, whereas isolates from treated plants had lower infectivities. Isolates from treated hosts other than *P. floridana* were compared against isolates from untreated plants from the same host. Isolates from 8-azaguanine-treated plants were considered to contain modified virus. An isolate with an infectivity of 60% of the standard was considered to contain 60% infective virus and 40% uninfective. For convenience, TMV from control plants was designated V, whereas the infective virus fraction from treated plants was designated V_t and the uninfective fraction V_m.

Results.—*Effect of time of application of 8-azaguanine.*—*P. floridana* plants were inoculated with 0.10 μg/ml of TMV, and 300 μg/ml of 8-azaguanine was applied at different intervals both before and after inoculation. Leaves were harvested 14 days after inoculation, and the virus was purified and assayed for infectivity. A series of tests of single applications of 8-azaguanine indicated that the 24 hours immediately after inoculation was the period most responsive to treatment (Fig. 1). The *P. floridana*-TMV system was also shown to be unusually responsive to applications of 8-azaguanine. Matthews (12) reported little difference in infectivity of virus from 8-azaguanine-treated plants compared to virus from control plants in 14-day TMV infections in tobacco.

For further studies, multiple application of 8-azaguanine 1 day before and 1 and 2 days after inoculation was adopted as standard.

Effect of time of harvest.—*P. floridana* plants were inoculated with 1.0 μg/ml TMV and treated with 1500 ppm 8-azaguanine 1 day before and 1 and 2 days after inoculation. Leaves were harvested at varying intervals after inoculation, and the virus was purified and assayed for infectivity. Virus development in treated plants was delayed (Fig. 2), and the maximum titer was less than in control plants. V_m reached a maximum about 17 days after inoculation, and then decreased. The assay methods were not sensitive enough to determine V_m accurately in infections older than 3 weeks. V_m exceeded V_t for the first 10 days. The number of primary infections was reduced about 98%, as evidenced by the reduction in total titer during the first week of infection.

A similar experiment with Turkish tobacco (Fig. 4) instead of *P. floridana* (Fig. 2) indicated that the rate of virus development in treated plants was a function of the host. The tobacco-TMV system was much less sensitive to the effects of 8-azaguanine than was the *P. floridana*-TMV system. In tobacco, V_m reached a maximum in about 9 days, and then decreased, and V_m never exceeded V_t. There was no effect on the number of primary infections, because the total titer of treated plants equaled that of control plants during the first week of infection.

Effect of inoculum concentration.—*P. floridana* plants were inoculated with concentrations of TMV from 10 mμg/ml to 7.6 μg/ml and treated with 600 μg/ml of 8-azaguanine as usual. Leaves were harvested at 7, 14, and 21 days. The results were similar for the first two harvests. Second harvest results are shown in Fig. 3. Virus accumulation was a function of the inoculum concentration, and the rate of increase of V_m with increasing concentrations of inoculum paralleled that of V_t. In the 21-day harvest there was a decrease in V_m at higher inoculum concentrations.

Effect of 8-azaguanine concentration.—*P. floridana* plants were inoculated with 10 μg/ml TMV and treated with 8-azaguanine in the usual manner in concentra-

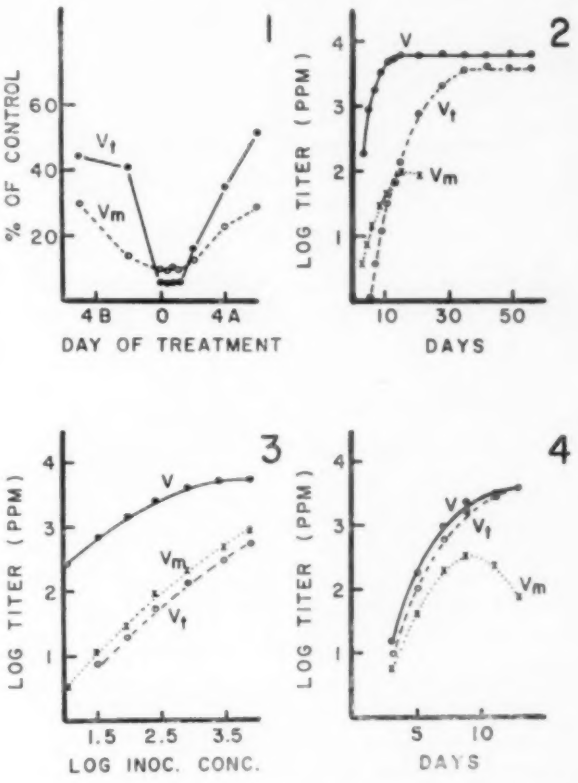


Fig. 1–4.—1) Effect of time of treatment with a single application of 300 ppm 8-azaguanine on production of infective (V_t) and uninfective (V_m) TMV in *Physalis floridana*. Inoculum concentration 0.100 ppm. Leaves harvested 14 days after inoculation. **2)** Effect of 3 applications of 8-azaguanine at 1500 ppm on rate of accumulation of infective (V_t) and uninfective (V_m) TMV in single leaves of *P. floridana* compared to virus accumulation in untreated plants (V). Titer in ppm of fresh weight. Inoculum concentration 1.00 ppm. **3)** Effect of inoculum concentration on relative proportions of infective (V_t) and uninfective (V_m) TMV in *P. floridana* treated with 3 applications of 600 ppm 8-azaguanine; compared to virus in untreated plants (V). Harvested 14 days after inoculation. Inoculum concentration in mμg/ml. **4)** Effect of 3 applications of 8-azaguanine at 1500 ppm on rate of accumulation of infective (V_t) and uninfective (V_m) TMV in single leaves of Turkish tobacco compared to virus accumulation in untreated plants (V). Titer in ppm of fresh weight. Inoculum concentration 1.00 ppm.

tions from 50 μg/ml to 4.0 mg/ml. Leaves were harvested at 7, 14, and 21 days. A similar experiment was performed with a TMV inoculum of 0.1 μg/ml. The results of the two tests were similar, and indicated that the amount of V_t varied inversely with the 8-azaguanine concentration, but V_m in general varied directly with the 8-azaguanine (Fig. 5). At higher concentrations of 8-azaguanine, less V_m was lost with time, so it is likely that V_m reverts to V_t in the host, the ratio of V_m/V_t depending on the 8-azaguanine concentration in the tissue.

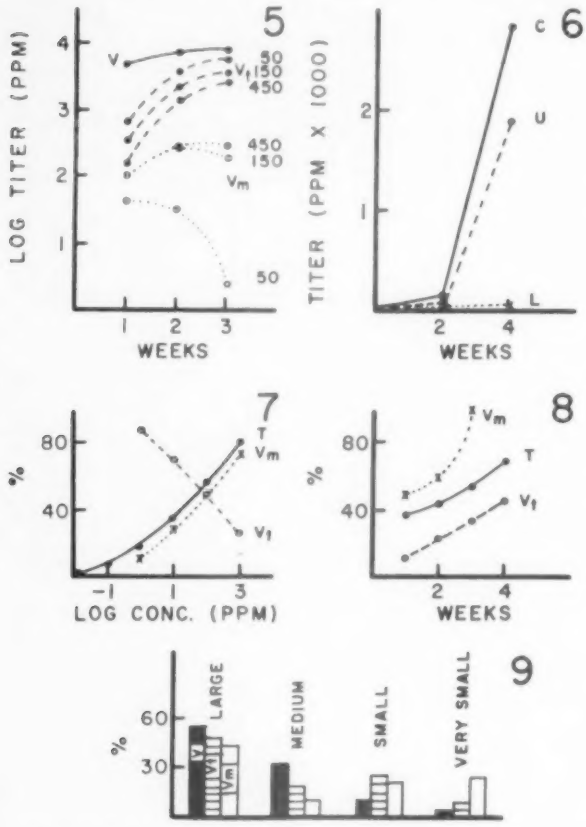


Fig. 5–9.—5) Effect of 8-azaguanine concentration on accumulation of infective (V_t) and uninfective (V_m) TMV in single leaves of *P. floridana* in comparison with the accumulation of virus in untreated plants (V). Three applications of 8-azaguanine at 50, 150, and 450 ppm. Inoculum concentration 10 ppm TMV. **6)** Effect of 8-azaguanine on accumulation of TMV in upper uninoculated leaf, when lower leaf on same *P. floridana* plant inoculated. C = no treatment; U = upper leaf treated; L = lower leaf treated. Three applications of 300 ppm 8-azaguanine. Lower leaf inoculated with 0.100 ppm TMV. **7)** Effect of concentration of single application of 8-azaguanine on relative proportions of infective (V_t) and uninfective (V_m) TMV in single leaf of *P. floridana* compared to percentage inhibition of total titer (T). Inoculum concentration 0.200 ppm TMV. Harvested 7 days after inoculation. **8)** G isolate in percentage of standard isolate showing accumulation of infective (V_t) and uninfective (V_m) TMV in treated *P. floridana* plants in comparison to total virus (T) in untreated inoculated at isolate contained 61% V_m. Both isolates inoculated at 0.200 ppm total virus. Three applications of 600 ppm 8-azaguanine on treated plants. **9)** Percentage of particles in various size classes of TMV from untreated *P. floridana* plants (V) and infective (V_t) and uninfective (V_m) TMV from treated plants. The size classes determined by centrifugation.

The minimum amount of 8-azaguanine required for effect on the *P. floridana*-TMV system was determined by applying concentrations of 8-azaguanine from .01 μg/ml to 1 mg/ml in a single application 1 day before inoculation with 0.2 μg/ml TMV. Leaves were harvested 7 days after inoculation. The results (Fig. 7) showed that about 0.01 μg 8-azaguanine/ml was the minimum for effect. V_m varied directly with the 8-azaguanine applied, whereas V_t varied inversely. Moreover, the per cent of V_m paralleled the per cent inhibition in total titer.

Effect of 8-azaguanine on local-lesion hosts.—Cucumber, *N. tabacum* var. NN, and *N. glutinosa* were treated with 1500 ppm 8-azaguanine 1 day before and 1 and 2 days after inoculation with varying concentrations of TMV. Local lesions were reduced about 50% in cucumber and *N. glutinosa*, regardless of the amount of TMV applied. This result indicates that 8-azaguanine acted on the host rather than on the virus. The 8-azaguanine had no effect on lesion numbers in the NN tobacco, further indicating that the effect of 8-azaguanine depends on the host.

The virus was purified from the excised necrotic lesions from *N. glutinosa* and NN tobacco, and assayed for total titer and infectivity, comparing isolates from treated and untreated plants. 8-azaguanine treatment had no effect on total titer of lesions, but treated lesions had 50% V_m in *N. glutinosa* and 63% V_m in NN tobacco.

Local lesions of TMV appeared 2 days later in treated *N. glutinosa* than in untreated plants. There was no apparent delay in lesion formation in NN tobacco. NN tobacco was thus similar to Turkish tobacco in that 8-azaguanine had little effect on primary infection sites and little effect on rate of virus increase.

Direct effect of 8-azaguanine on TMV.—TMV in various concentrations of 8-azaguanine for various periods was removed by centrifugation and inoculated to cucumber cotyledons. Such treatments did not affect the virus infectivity. In other studies, 8-azaguanine was mixed directly with the inoculum in various concentrations, and again there was no effect on the number of TMV lesions in cucumber. The only case where reduction in lesion number occurred was when the cucumber plants themselves were treated with 8-azaguanine plus a surfactant before and after inoculation.

Effect of 8-azaguanine on systemic virus distribution.—*P. floridana* plants were pruned to 2 leaves, and only the lower leaf was inoculated. 8-azaguanine was applied 1 day before and 1 and 2 days after inoculation. In one group of plants the inoculated leaf was treated, whereas in another group the upper leaf was treated. Both upper and lower leaves were harvested after 2 and 4 weeks, and the virus purified and assayed for total titer. 8-azaguanine treatment of the lower leaf markedly reduced the rate of virus accumulation in the upper leaf (Fig. 6). There was a much greater

effect on reducing systemic virus spread than on reducing titer in a treated leaf. When either the inoculated (lower) leaf or the upper leaf was treated, total titer of these leaves was reduced about 50%. The titer of the upper leaf, however, was reduced 98% when the lower leaf was treated. It appears that 8-azaguanine, in addition to reducing the number of initial infective sites and inducing the production of modified virus, also reduces virus translocation or movement in the host.

8-azaguanine-treated virus as inoculum.—A dilution series of TMV from 1.0 to 0.01 μg/ml was inoculated to cucumber and compared on paired cotyledons with a similar series containing a constant 0.10 μg/ml of an isolate from *P. floridana* containing 80% V_m. A duplicate experiment was made, but with the V_m isolate at 1.0 μg/ml. The presence of V_m and V_t in the inoculum had no effect on the numbers of V lesions. The total lesions in the combined inoculum series were proportional to the total $V + V_t$ concentration in the inoculum. It was apparent that, over the concentration range used, V_m does not interfere with the production of V or V_t lesions.

The standard TMV isolate was compared in both untreated and treated *P. floridana* with an isolate from treated *P. floridana* plants that contained 61% V_m (Isolate G). Both isolates were diluted to 0.2 μg/ml total virus for inoculation, and 600 ppm 8-azaguanine was used for treatment. Leaves were harvested weekly for 4 weeks after inoculation. The results (Fig. 8) showed that treated plants contained relatively more V_m and less V_t from the G isolate than from the standard isolate. The G isolate was thus more susceptible to 8-azaguanine treatment than the standard isolate. No V_m could be detected in untreated plants inoculated with either isolate; therefore, V_m must not be infective, or at least does not increase as such in *P. floridana*. On the other hand, V_t must increase, because the G isolate was more susceptible to 8-azaguanine treatment than the standard isolate. V_t therefore, is not identical to V.

Effect of temperature.—*P. floridana* plants inoculated with 0.1 μg/ml TMV and treated with 300 ppm 8-azaguanine were kept at 32°C after inoculation. Leaves were harvested 1 and 2 weeks after inoculation. Both control and treated plants produced virus at a higher rate at 32°C than comparable plants grown at 20°C. At 32°C, however, V_m reverted to V_t at a faster rate so that the peak V_m concentration occurred much earlier.

Axillary buds were allowed to grow on these plants. No TMV symptoms were produced on treated plants, but typical symptoms were evident on the controls. The total titer of the secondary growth after 2 weeks was 2000 μg/g on the controls, and only 260 μg/g on the treated plants. The lower titer probably accounted for the lack of symptoms, and is further evidence that treatment reduces the rate of systemic virus spread.

Purified preparations.—A number of unsuccessful attempts were made to fractionate purified virus preparations from treated plants in order to separate V_m, V_t, and V. On electrophoresis, only a single sharp peak was obtained. No separation was achieved with paper electrophoresis. Separation was only partial with paper chromatography using various solvents.

An analytical centrifuge was not available, but tests made with the preparative centrifuge indicated that V_m sedimented slower than V_t, which sedimented slower than V (Fig. 9). In these tests, samples of both pellet and supernatant were tested for infectivity after 5, 10, and 20 minutes' centrifugation. The size classes were defined as the amount of virus sedimented at these time intervals; the very small size being the unsedimented virus after 20 minutes' centrifugation. This was additional evidence that V_t differed from V. It also appeared that differences between V_t and V_m were quantitative.

Ultraviolet (UV) absorption spectra of purified virus isolates from treated plants were similar to those from control plants except that the density ratio (230/260 mμ) of control isolates averaged 3.14, compared with 2.35 for treated isolates. These results could be due to quantitative differences in protein-nucleic acid ratios, or to qualitative differences that would allow for greater UV absorption at 260 mμ in treated isolates.

Since the quantitative data reported in this paper were based on density measurements, it was desirable to determine the reason for this difference in UV absorption. RNA (ribonucleic acid) and protein were separated by the glacial acetic acid method (1), and the relative quantities of each were determined spectrophotometrically. RNA was estimated by density measurements at 260 mμ, and protein at 280 mμ. Amounts of RNA obtained with this method were comparable to those with the phenol method (3). The ratio of protein to nucleic acid averaged 15.7 for control isolates and 21.2 for treated isolates. This is equivalent to 6.0% nucleic acid in the control isolates and 4.5% in the treated isolates. These results are the reverse of the spectrophotometric results on intact virus. Thus, although density measurements at 260 mμ would give results that were apparently 25% high on intact virus from treated plants, this error is compensated because there is actually 25% less RNA present. The net result is that density measurements on intact virus for treated and control isolates are comparable.

In TMV particles, no structural differences between treated and control isolates could be detected when examined by electron microscopy by Dr. A. H. Gold, University of California.

When RNA was isolated from control virus by the phenol method (3) and its infectivity determined on cucumber, it was found to be only 0.2% as infective as intact virus. RNA from a treated isolate containing 20% V_m was compared with RNA from control virus and found to be only 1/6 as infective, which infectivity was only 1/5 of that expected. It is not clear why the RNA from the treated isolate was so low in infectivity.

A number of attempts were made to determine the amount of 8-azaguanine incorporated into treated iso-

lates following the procedures used by Matthews (12), but the amounts incorporated were below the sensitivity of the method (1%). Since a TMV particle has approximately 2000 guanine units, considerable 8-azaguanine can be substituted and not be detected by the methods used.

Discussion.—The following effects of 8-azaguanine appear to be important: 1) inhibition of virus replication sites; 2) production of V_m with a low order of infectivity; 3) production of V_t with a high order of infectivity; and 4) a reduced rate of systemic virus spread. There was little evidence of a reduced rate of virus synthesis as a result of inhibition of normal host protein or nucleic acid metabolism. The only case where this might have occurred was that of a 2-day relay in appearance of necrotic lesions in *N. glutinosa*. Even in this case, lesion development may have been slowed by a reduced rate of movement of virus to neighboring cells or because V_m delayed the necrotic reaction of the host. In *P. floridana* it is evident that 8-azaguanine may inhibit over 90% of initial infection sites (Fig. 1, 2). Furthermore, the maximum virus yield is some 30% lower in treated than in control plants, indicating that total replication sites may be reduced by this amount (Fig. 2). With increasing concentrations of TMV in the inoculum, the amount of V_t in treated plants parallels the amount of V in control plants (Fig. 3). The difference between the curves can be accounted for by the effect of 8-azaguanine on site inhibition. If rate of virus replication were affected by a disturbance in host protein or nucleic acid metabolism, it would be expected that the V_t curve would have a flatter slope. These results agree with those of Matthews on 8-azaguanine (7, 13), but are in contrast to those of Porter and Weinstein (16) on thiouracil, where there was a marked effect on the host.

V_m and V_t are relative terms chosen for convenience, but may have no real meaning because there may be intergrades. Thus, although V_m was chosen to represent those virus particles that are not infective in cucumber, in reality it may be those particles that have a low order of infectivity, whereas V_t represents those particles with a higher order of infectivity. Since the concentration of V_m in treated plants rises to a maximum and then declines (Fig. 2, 4, 5) it is apparent that the V_m reverts to V_t and that rate of reversion is a function of 8-azaguanine concentration and temperature. This is not surprising, since Matthews (9) showed that the effects of 8-azaguanine can be reversed by adenine, guanine, and possibly hypoxanthine.

The mechanism of action of 8-azaguanine does not appear to be a simple substitution of 8-azaguanine for guanine during virus RNA synthesis, because the V_m/V_t ratio depends on time of application of 8-azaguanine (Fig. 1). A more plausible explanation is that 8-azaguanine directly modifies the replication site, resulting in the production of modified virus. The replication sites can be represented as -s, $-s_t$, $-s_m$, and $-s_x$ in increasing order of site modification; and the reactions of these sites as $-sV=V$, $-s_tV=V_t$, $-s_mV=V_m$, and $-s_xV=0$. Since there are some 2000 guanine residues per TMV particle, considerable variability is probable in quantity as well as in actual positions of the substitutions, but it is not clear whether certain 8-azaguanine substitutions in the virus particle are more effective than others. The work of Smith and Matthews (19) suggests that the substitution is not random. Maximum substitution reported by Matthews (12) was 3% of the guanine, whereas in our work it was less than 1%. At the maximum, then, there would be an average of 60 substitutions per TMV particle, but the range may be from 0 to several hundred. V_t would represent a low order of substitution and V_m a moderate order, on a quantitative basis. There would be a similar situation on the replication site, with X representing a high order of substitution, M a moderate and T a low order.

The number of completely inhibited virus replication sites may be approximated by the per cent inhibition in total titer. It is apparent that the proportion of V_m parallels the per cent inhibition in total titer, and both are a function of the 8-azaguanine concentration (Fig. 7) and the time of application of 8-azaguanine (Fig. 1). The proportion of V_m and the per cent titer inhibition are independent of amount of applied TMV (Fig. 3).

The effect of 8-azaguanine in inhibiting systemic virus development appears greater than can be accounted for by replication site inhibition. There are several possible mechanisms. 8-azaguanine might inhibit virus movement into or out of the phloem. If the translocation form of TMV is pure RNA, as suggested by the work of Cochran and Chidester (2), then the inhibition in systemic development might be due to reduced infectivity of the RNA, because RNA from virus of treated plants had only 1/5 the expected infectivity, based on comparative infectivity of whole virus.

Variation in host-virus response to 8-azaguanine may be due to several factors. The different rates of deamination of 8-azaguanine to 8-azaxanthine by guanase (11) or the change of 8-azaguanine by other enzyme systems in different hosts may be important. Another mechanism that may be involved is the configuration of the virus replication site in the host. Thus, 8-azaguanine may be more readily attached to a replication site in one host than in another host. In *P. floridana* (Fig. 2) there was an initial inhibition of total titer of 99% with treatment, leveling off to 32% in 40 days. Contrasted with this was tobacco (Fig. 4), in which there was little to no inhibition in total titer. V_m in per cent of total titer was 4 times as great in *P. floridana*; moreover, the V_m concentration declined faster in tobacco. Thus, both enzyme activity and site configuration may be involved in the differences between these two hosts.

V_t used as inoculum (Fig. 8) was more susceptible to 8-azaguanine treatment than normal virus, which implies that 8-azaguanine actually induced the virus to mutate to V_t and the uninfective V_m. The mutant

viruses, however, did not interfere with production of lesions by normal virus in mixed inocula. Moreover, since the change $V \longrightarrow V_t \longrightarrow V_m$ appears to be reversible, the mutation is a very unstable one, dependent upon the 8-azaguanine level in the host tissue. —Department of Plant Pathology, Washington State University, Tree Fruit Experiment Station, Wenatchee, Washington, and Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Wenatchee, Washington.

LITERATURE CITED

1. Bawden, F. C., and N. W. Pirie. 1937. The isolation and some properties of liquid crystalline substances from solanaceous plants infected with three strains of tobacco mosaic virus. Proc. Roy. Soc. B 123:274-320.

2. Cochran, G. W., and J. L. Chidester. 1957. Infectious nucleic acid in plants with tobacco mosaic. Virology 4: 390-391.

3. Gierer, A., and G. Schramm. 1956. Die Infektiosität der Nucleinsäure aus Tabakmosaikvirus. Z. Naturforsch. 11 b:138-142.

4. Kirkpatrick, H. C., and R. C. Lindner. 1954. Studies concerning chemotherapy of two plant viruses. Phytopathology 44:529-533.

5. Lindner, R. C., H. C. Kirkpatrick, and T. E. Weeks. 1955. Some factors affecting the purification of a stone fruit virus. Phytopathology 45:574-576.

6. Lindner, R. C., H. C. Kirkpatrick, and T. E. Weeks. 1959. Some factors affecting the susceptibility of cucumber cotyledons to infection by tobacco mosaic virus. Phytopathology 49:78-88.

7. Matthews, R. E. F. 1951. Effect of some substituted purines on the development of plant virus infections. Nature 167:892-893.

8. Matthews, R. E. F. 1952. Effect of purines on the multiplication of plant viruses. Nature 169:500-501.

9. Matthews, R. E. F. 1953. Chemotherapy and plant viruses. J. Gen. Microbiol. 8:277-288.

10. Matthews, R. E. F. 1953. Incorporation of 8-azaguanine into nucleic acid of tobacco mosaic virus. Nature 171:1065-1066.

11. Matthews, R. E. F. 1953. Proc. 6th Intern. Congr. Microbiol. Rome 3:1439.

12. Matthews, R. E. F. 1954. Effects of some purine analogues on tobacco mosaic virus. J. Gen. Microbiol. 10: 521-532.

13. Matthews, R. E. F. 1955. Infectivity of turnip yellow mosaic virus containing 8-azaguanine. Virology 1: 165-175.

14. Matthews, R. E. F., and J. D. Smith. 1955. The chemotherapy of viruses. *In* Advances in Virus Research III: 49-148. Academic Press, N. Y. 10, N. Y.

15. Nickell, L. G., P. Greenfield, and P. R. Burkholder. 1950. Atypical growth of plants. III. Growth responses of virus tumors of Rumex to certain nucleic acid components and related compounds. Botan. Gaz. 112:42-52.

16. Porter, C. A., and L. H. Weinstein. 1957. Biochemical changes induced by thiouracil in cucumber mosaic virus-infected and noninfected tobacco plants. Contribs. Boyce Thompson Inst. 19:87-106.

17. Russell, G. E., and A. R. Trim. 1957. Effects of 8-azaguanine on sugar beet infected with beet yellows virus. Nature 179:151.

18. Schlegel, D. E., and T. E. Rawlins. 1953. A comparison of two methods of preparing tobacco mosaic virus for spectrophotometric assay. Phytopathology 43:89-91.

19. Smith, J. D., and R. E. F. Matthews. 1957. The metabolism of 8-azapurines. Biochem. J. 66:323-333.

20. Takahashi, W. N. 1951. Ultraviolet absorption as a measure of tobacco mosaic virus nucleoprotein. Phytopathology 41:142-145.

RELATIONSHIPS AMONG ISOLATES OF PSEUDOMONAS SYRINGAE PATHOGENIC ON STONE FRUIT TREES

Gerardo Perlasca

Formerly Research Assistant, Department of Plant Pathology, University of California, Davis; now Plant Pathologist and Geneticist, Campbell Soup Company, S.p.A., Riverton, New Jersey.

Part of a Ph.D. thesis, University of California, Davis.

Accepted for publication June 28, 1960.

The author gratefully acknowledges the guidance of Dr. J. E. DeVay during the study and preparation of the manuscript.

SUMMARY

Single-cell derivatives of 4 isolates of *Ps. syringae*, although they originated from a limited geographical area, showed a considerable range of variability in pathogenic, antigenic, and phage relationships.

The presence of cells of different virulence in the populations of certain pathogenic isolates, originally purified by dilution plate techniques, was evident when single-cell derivatives were obtained. Pathogenicity and virulence of the resulting clones on several host plants were constant.

Antigenic analysis indicated a considerable degree of heterogeneity among the isolates, preventing reduction to a single serological group. Serologically indistinguishable virulent and avirulent individuals were observed. Pathogenicity was not associated with any particular antigenic type or structure. Isolates D15A and P3 fulfilled Krumwiede's postulate of serological likeness or identity—a complete positive reciprocal agglutination absorption was observed in all tests. The isolates were serologically identical although their pathogenicity was different.

Infection of the bacterial clones with phages showed that isolates D15A and P3, antigenically identical, were also consistently lysed by the same phages. The response of other isolates to these phages varied. On the basis of phage sensitivity a possible relationship was evident between isolates D15, D15A, P3, and H-D. The few phages tested, however, did not permit the selection of phages specific on bacterial isolates with certain characteristics such as pathogenicity, or of phages capable of lysing all isolates tested.

The lytic reaction was more common among the isolates than the agglutination reaction, indicating that the cell surface characteristics for phage attachment were more commonly shared by the bacterial isolates. Relative plating efficiency was highly variable. No phage specific for any bacterial isolate was found and variation among the phages themselves was evident.

Introduction.—Bacterial canker and blast of stone fruits caused by *Pseudomonas syringae* Van Hall are of world-wide distribution but are particularly severe along the Pacific Coast of the United States and in

England, Holland, New Zealand, and Australia.

The causal agent includes a group of usually green-fluorescent bacteria that can be isolated from a number of sources, including both diseased and healthy plant tissues.

The classification of species of *Pseudomonas* causing bacterial canker and blast of stone fruits is still controversial (3, 5, 6, 8, 9, 10, 12, 20, 22, 28, 29, 30, 31, 32, 33, 34). Wilson (32) and Fuchs (12) found it impossible to distinguish *Ps. syringae* from *Ps. prunicola* Wormald or *Ps. mors-prunorum* Wormald on the basis of biochemical, pathogenic, and cultural characteristics. The wide range of host plants attacked includes, besides stone fruits, annual and perennial herbaceous plants. Furthermore, isolates of *Ps. syringae* may differ in certain biochemical and physiological characters, increasing the difficulty of identification and classification (3, 10, 20, 22, 30). These facts reflect the great range of variability in this species.

Serological studies (11, 19, 20, 21, 23) have indicated the existence of a great number of special forms among the pseudomonads; several workers have been able to isolate phages attacking these bacteria (7, 13, 14, 15, 18) but the response to phage and the degree of plant pathogenicity were not correlated.

The present study was made to determine among isolates of *Ps. syringae* found in California the range of variability as reflected in pathogenic, antigenic, and phage relationships.

Materials and methods.—*Origin of isolates.*—The organisms used were selected from a stock of bacterial cultures maintained in the Department of Plant Pathology, Davis, California. The four isolates finally chosen were representative of the pathogenic range of the stock and had common characters fitting the classification of *Ps. syringae*. Their origin was as follows: D78, rain washings from almond trees (March, 1957); D15, washings from healthy almond leaves (December, 1956); P3, peach cankers (spring, 1956); H-D, cherry cankers (May, 1956).

Preceding the study the isolates had been grown 1–2 years on artificial media. Their pathogenic behavior was as follows: D78, weakly virulent; D15 and P3, highly virulent on peach trees but weakly virulent on beans; and H-D, highly virulent on beans but weakly virulent on peach trees.

Culture media.—The liquid media used were: 1) nutrient broth (0.3% beef extract Difco, 0.5% Bacto-peptone, and 2% glycerol in distilled water); and 2) potato-dextrose broth (200 g of peeled potatoes boiled 15 minutes in 1 L of tap water; the broth was filtered, autoclaved, and stored overnight at 7°C; the supernatant decanted, adjusted to 1 L with tap water containing 30 g of dextrose, and autoclaved again).

Unless otherwise stated, bacteria in liquid media were incubated on a New Brunswick rotary shaker at 213 rpm at an average temperature of 25°C.

The formation of a green-fluorescent pigment by various bacterial isolates was evaluated on the following semisolid agar medium: 1.0% bacto-agar, 1.0% proteose-peptone (no. 3), 1.0% glycerol, 0.3% magnesium sulfate, 0.3% dipotassium phosphate, and 0.1% potassium dihydrogen phosphate in distilled water.

Single-cell isolations.—Single-cell derivatives of each isolate were obtained following Lederberg's method (17).

Droplets 60–100 μ in diameter of suitable dilutions of bacteria in NB (nutrient broth) were first searched with the 10× objective in combination with the annulus for the 43× objective of a phase microscope. The resulting dark field enhanced the possibility of observing fast-moving bacteria and quickly selecting the droplets with one bacterial cell. Suitable droplets were then carefully searched with the 43× dark M objective with the annulus properly set.

The slides with droplets containing only one cell were incubated 24 hours at 25°C in a leveled sterile Petri dish lined with moist filter paper. Of the single cells isolated, 20–80% multiplied; these were transferred with a capillary pipette to tubes containing 10 ml of NB.

Lyophilization.—Suspensions of single-cell derivatives were lyophilized in skim milk according to the procedure described in the Manual of Microbiological Methods of the Society of American Bacteriologists (24).

Pathogenicity tests.—Inocula were prepared by growing the bacteria overnight in NB. Turbidity of the cultures was adjusted to an optical density of 0.6 (10^8 cells/ml) with the Bausch and Lomb Spectronic 20 Colorimeter set at a wave length of 600 mμ. Optical density was measured in Pyrex tubes 13 mm in diameter.

All plants used for inoculations in the greenhouse were grown in sterile U. C. soil mix C fertilizer II (2).

Trifoliate leaves of 2-week-old bean plants were inoculated by twisting the large end of an infested #2 cork on the upper leaf surface. Inoculated plants were incubated 24 hours in a moist chamber averaging 20°C.

Stems of Lovell peach seedlings 12–18 in. long were pricked with a needle previously dipped into a bacterial suspension. Wet sterile cotton was then wrapped around the inoculation site and left for 24 hours. Inoculated seedlings were incubated at 20°C in moist chambers illuminated with artificial light; after 1 week, the lengths of the resultant lesions were measured.

During March, Long Stem Bing, Mazzard cherry, and Red Haven peach trees, 8–10 years old, were inoculated in the orchard. Branches 1 in. in diameter were inoculated with bacterial suspensions. After the surfaces of the branches were wiped with 70% ethanol, a needle was inserted transversally under the bark and 0.1 ml of the inoculum was injected with a hypodermic syringe. The openings were sealed with Scotch tape, and the length of the cankers measured after 4 weeks.

Green pods of Red Kidney beans, grown in the greenhouse, were harvested when the pods were full

length, the seeds partly developed, and the seed coats not yet colored. The surface of the pods was treated with 70% ethanol and pricked lightly under droplets of bacterial suspensions with a needle. Inoculated pods were placed in sterile test tubes lined with strips of wet filter paper and kept at 23–25°C. Diameter of the resultant lesions was recorded after 2 days.

Serology.—Five single-cell derivatives of *Ps. syringae* were included: D78, D15A, P3, H-D, and H-E. Cells from nutrient agar cultures were lyophilized to ensure that bacteria used in the agglutination tests would be, as much as possible, similar to the cells used for the immunizing antigens. The pathogenicity of the isolates was checked as previously described in the laboratory, in the greenhouse, and in the field.

Cultures from 2 transfer generations, incubated each time in PDB (potato-dextrose broth) for 72 hours at 25°C on a rotary shaker, were used to prepare the immunizing antigens. Cells were precipitated in 10 volumes of acetone and transferred to a sterile mortar. The cells were then dried for 3–4 hours in a vacuum desiccator. The clumps of dry cells were ground to a fine powder, suspended in 1*M* NaCl (1 g dry cells per 50 ml of salt solution), and agitated on a rotary shaker for 15 minutes. The suspension was centrifuged 15 minutes at about 25,000× gravity in a Spinco ultracentrifuge and the supernatant decanted into a 15/8-in. cellulose casing.

The extract was dialyzed in distilled water at 7°C for 24 hours to a dilution of about 0.14*M* NaCl. The dialyzed extract was sterilized by filtration before being used as immunizing antigen.

Antisera were prepared from New Zealand white rabbits (does), 5–6 lb, that before immunization were negative for specific agglutinins of the test antigens.

Immunization was accomplished with 11 injections in the marginal ear veins. The initial dose of 0.25 ml was increased daily by 0.25 ml up to 2 ml. This maximum dose was given daily until the tenth day. A final immunization of 2 ml was given following a rest of 4 days. Two animals were used for each isolate. Five days after the last injection the rabbits were bled by cardiac puncture. After clotting, the blood sample was stored overnight at 7°C. It was then centrifuged and the supernatant serum withdrawn and mixed with 0.01% merthiolate and stored in the refrigerator at 4°C.

Test antigens were prepared by reviving in NB the previously lyophilized cultures, which were simultaneously tested for pathogenicity and purity. Cultures 18 hours old, grown in PDB, were killed by keeping them at 60°C for 45 minutes, then centrifuged 4 times for 15 minutes at about 14,000× gravity; after each centrifugation the sedimented cells were resuspended in 0.14*M* NaCl. The final suspension had a cell density comparable to 1.5–2 by the McFarland turbidity standard (1 ml 1% $BaCl_2$ in 98 ml 1% H_2SO_4).

The methods of Krumwiede et al (16) for aggluti-

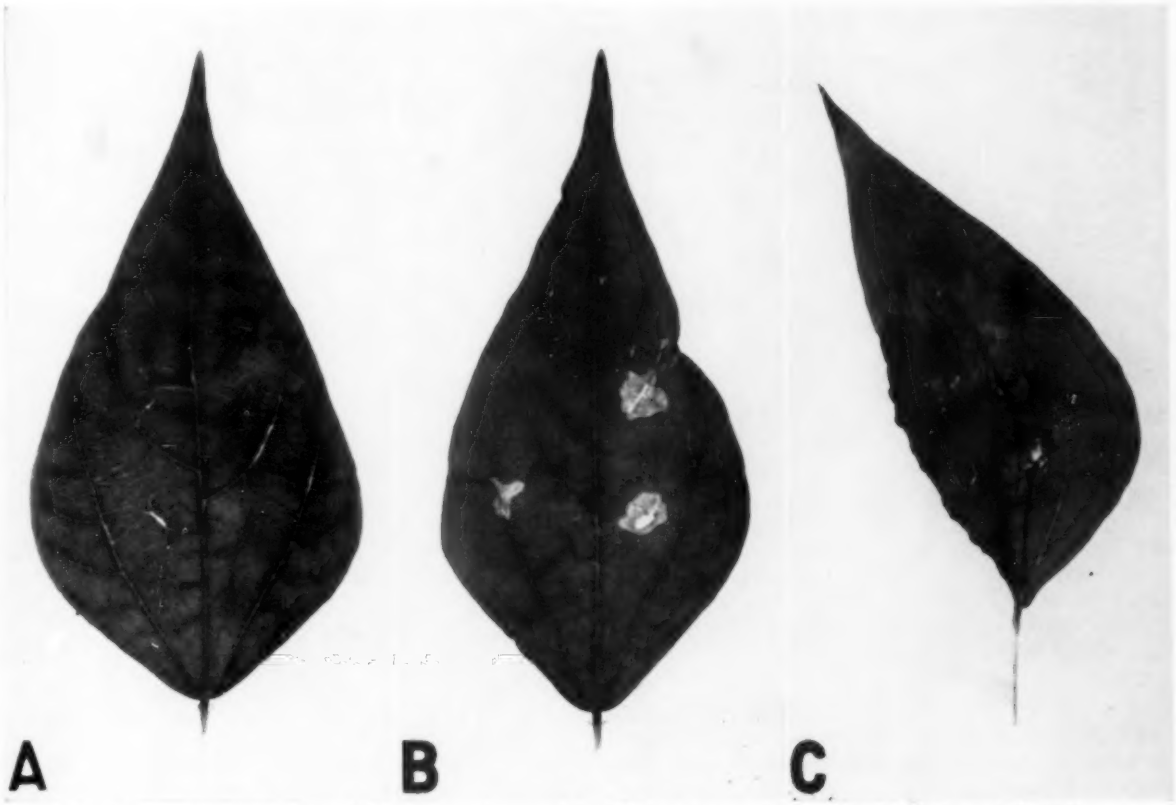


Fig. 1.—Lesions caused by bacterial isolates on leaves of Red Kidney beans. **A)** control; **B)** D15; and **C)** H-D.

nation and reciprocal agglutination absorption were followed to determine the antibody titer of each antiserum for homologous and heterologous reactions. Titers were recorded as the reciprocal of the last dilution of antiserum showing definite agglutination.

One-half-ml amounts of antisera, diluted 2 to 25,600 times with 0.14*M* NaCl, were mixed with 0.5-ml amounts of test antigen in Kahn tubes. The mixtures were incubated 2 hours at 37°C, then overnight at 7°C.

For reading the degree of macroscopic agglutination the tubes were set side by side in a wooden rack and examined under oblique light. Clumped cells were resuspended by lowering the rack of tubes to a horizontal position momentarily, then returning it to an upright position. The tubes were thus handled uniformly and the degree of agglutination easily determined.

Bacteriophagy.—Samples of Yolo clay loam were collected in July at Davis from 1–2 in. below the soil surface beneath peach, almond, cherry, plum, and apricot trees.

Phages were isolated by the soil enrichment technique. The methods used to isolate and purify phages in the soil extracts and to prepare stocks of various phages were essentially those of Adams (1). At least 3 successive single-plaque transfers were made before phage stocks were prepared.

Electron microscopy, by the method of Williams and Fraser (27), was conducted on phage stocks that were purified by differential centrifugation and air-

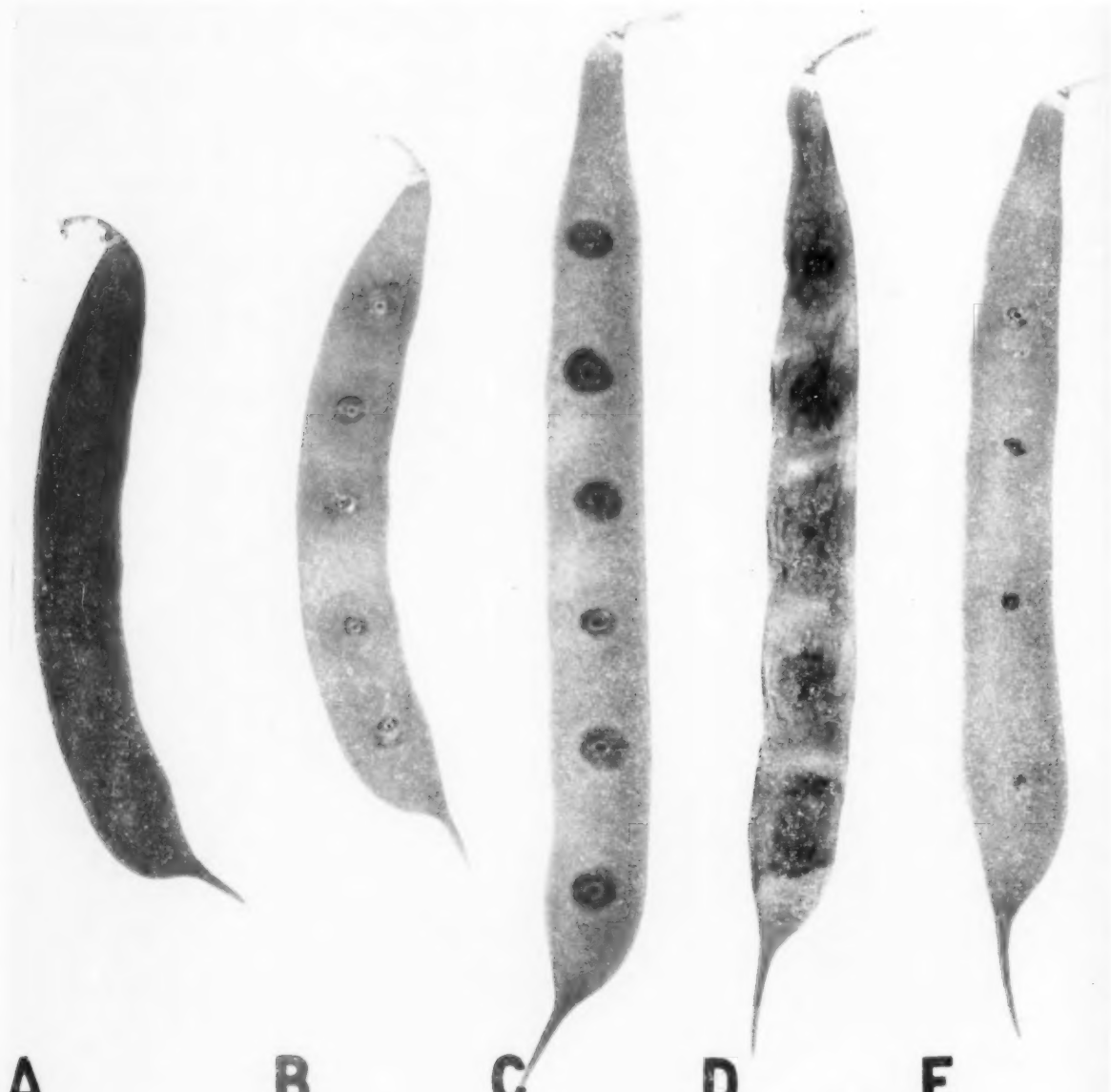


Fig. 2.—Lesions caused by bacterial isolates on pods of Red Kidney beans. **A)** control; **B)** D15; **C)** H-D; **D)** H-DA, and **E)** H-E.

dried. One hundred and fifty ml of a 12-hour-old culture in NB were transferred to an aerated glass tube (input ratio of phage to bacteria 1:100). Turbidity was measured every 2 hours with a Bausch and Lomb Spectronic 20 Colorimeter (600 m μ) and lysates centrifuged at maximum lysis.

Five successive centrifugations were made, alternately 5 minutes at about 3,000× gravity and 60 minutes at about 6,000× gravity. Pellets were resuspended in distilled water, but final suspensions were in 0.05% OsO_4. Infectivity of pure preparations was verified, and suitable dilutions sprayed on 200-mesh electron microscope grids with a Vaponefrin glass nebulizer.

Results.—*Pathogenicity tests.*—Results in pathogenicity tests were similar for bacterial suspensions in NB, washed cells centrifuged and resuspended in NB, and bacteria scraped from slants into sterile distilled water. When cultures of the pathogenic isolates were filtered (Millipore filter, pore size 0.45 mμ), the sterile filtrates did not cause disease.

On pods and leaves of Red Kidney beans, infecting doses of 10^6 bacterial cells were used; a 1:100 dilution of this inoculum density greatly reduced disease development, whereas at higher doses up to 10^9 cells the virulence of the organisms remained the same. There was no difference between attached and detached pods in disease reaction.

Isolates D78 and H-E were avirulent when inoculated on bean leaves in the greenhouse, whereas isolates D15 and P3 produced necrotic lesions limited to

Fig. 3.—Infection of Lovell peach seedlings. **A)** Isolate P3 caused severe necrosis girdling the stem and affecting uninoculated lateral branches; leaves entirely necrotized and gum produced. **B)** Isolates H-D produced lesions limited to the side of inoculation; leaves and lateral branches unaffected.

Table 1.—Pathogenic behavior of 6 isolates of *Pseudomonas syringae* on different hosts.

Bacterial isolate	Red kidney bean leaves	Maximum lesion length or diameter (mm)		
		Red kidney bean pods	Lovell peach seedlings	Long Stem Bing cherry branches
D78	avirulent	avirulent	avirulent	avirulent
D15	limited necrosis	5	70	50
D15A	limited necrosis	2	15	5
P3	limited necrosis	5	70	60
H-D	widespread necrosis	20	15	10
H-E	avirulent	avirulent	avirulent	avirulent

the inoculated area, and H-D was highly pathogenic, causing a widespread necrosis (Fig. 1).

On pods of Red Kidney beans H-D was highly pathogenic, causing extensive brown lesions. As few as 5–10 cells, determined by direct count, were able to initiate infection. Marked variation in virulence was found in cultures of H-D purified by dilution plate technique; one single-cell derivative, H-DA, was more virulent than the parent culture, whereas another single cell derivative H-E was less virulent (Fig. 2). The reaction of isolate H-E on pods of Red Kidney beans was not changed after 8 successive inoculations and reisolations under laboratory conditions.

In greenhouse tests on seedlings of Lovell peach, isolates D78 and H-E were avirulent, whereas H-D and D15A produced dark-brown lesions up to 15 mm long, extending in both directions from the point of inoculation. Isolates D15 and P3 caused lesions up to 70 mm long, often girdling the stems, affecting lateral branches, and resulting in complete necrosis of the leaves (Fig. 3). It was also found that the younger tissues in upper half of the stems of peach seedlings were more susceptible to canker than the lower part. The virulence of the bacterial isolates was similar in both greenhouse and field tests. The pathogenic behavior of the isolates on various hosts is given in Table 1.

Serology.—Lyophilized cultures that were revived and used for antigens were free of contaminants and gave on beans and peach seedlings the same response recorded in previous pathogenicity tests.

Titer data for homologous and heterologous reactions of isolates D78, D15A, P3, H-D, and H-E are summarized in Table 2. Fig. 4 is representative of the agglutination reactions observed.

Isolates D15A and P3 were agglutinated at the same titer in cross-agglutination tests as in their respective homologous reactions (Table 2, lines 7 and 13). Cross-agglutination with antisera of other isolates also confirmed the antigenic similarity of isolates D15A and

Table 2.—Serological analysis of five isolates of *Ps. syringae*.[a]

Line	Antiserum	Absorbed with organism	Titer when tested with organism				
			D78	D15A	P3	H-D	H-E
1	D78	Unabsorbed	3200	200	200	25	0
2		D78	0	0	0	0	0
3		D15A	800	0	0	0	0
4		P3	800	0	0	0	0
5		H-D	3200	200	200	0	0
6		H-E	1600	200	200	0	0
7	D15A	Unabsorbed	0	3200	3200	5	0
8		D78	0	1600	1600	0	0
9		D15A	0	0	0	0	0
10		P3	0	0	0	0	0
11		H-D	0	1600	1600	0	0
12		H-E	0	1600	1600	0	0
13	P3	Unabsorbed	10	3200	3200	5	0
14		D78	0	1600	1600	0	0
15		D15A	0	0	0	0	0
16		P3	0	0	0	0	0
17		H-D	0	1600	1600	0	0
18		H-E	0	800	1600	0	0
19	H-D	Unabsorbed	0	0	5	3200	200
20		D78	0	0	0	3200	0
21		D15A	0	0	0	3200	0
22		P3	0	0	0	1600	0
23		H-D	0	0	0	0	0
24		H-E	0	0	0	400	0
25	H-E	Unabsorbed	0	200	200	400	1600
26		D78	0	0	0	0	1600
27		D15A	0	0	0	0	800
28		P3	0	0	0	0	800
29		H-D	0	0	0	0	800
30		H-E	0	0	0	0	0

[a] Figures indicate the reciprocal of the last dilution of antiserum showing definite agglutination.

Table 3.—Characteristics of 7 phage stocks used to study relationships among isolates of *Ps. syringae* and related bacteria.

Phage	Soil enriched with organism	Plaque morphology
1	D15A	pinpoint turbid
2	D15	3 mm turbid
3	P3	pinpoint turbid
4	P3	0.5-1 mm turbid
5	P3	2-3 mm turbid
6	P3	2-3 mm clear
7	—	1-2 mm clear, a mutant of 5

P3 (Table 2, lines 1, 19, and 25). A weak antigenic relationship was apparent between D78 and P3 or D15A. In contrast, no antigenic relationships were found in heterologous reactions involving D78 and H-D or H-E isolates. Isolate H-E showed a weak antigenic relationship with D15A and P3. A weak relationship was also apparent between isolates H-D and H-E.

These antigenic relationships were further tested in reciprocal agglutination absorption tests. Absorption of each antiserum with its homologous antigen removed all the antibodies, as indicated by subsequent negative agglutination reactions in homologous systems. Treatment of each antiserum with a heterologous antigen removed any antibodies specific for that particular antigen. The degree of antibody absorption by heterologous antigens was taken as a measure of serological identity between the homologous and heterologous antigens based on the interpretation of Krumwiede et al (16).

Antiserum of isolate D78 absorbed with antigens of D15A and P3 (Table 2, lines 3 and 4) reduced the titer of the homologous reaction, showing a weak antigenic relationship. Absorption of antiserum of isolate D78 with antigens of both H-D and H-E isolates (Table 2, lines 5 and 6), did not alter the titer of the homologous reaction significantly, indicating little or no antigenic relationship.

Antiserum of D15A absorbed with antigens of D78 (Table 2, line 8) did not significantly alter the titer of the absorbed serum for D15A and P3, again indicating little or no antigenic similarity between D78 and D15A or P3. Absorption of antiserum of D15A with antigen of P3 and vice versa (Table 2, lines 10 and 15) showed complete absorption in subsequent agglutination tests, indicating that isolates D15A and P3 were antigenically identical. Absorption of antiserum D15A with antigens of both H-D and H-E (Table 2, lines 11 and 12) did not significantly alter the titer of the absorbed serum for D15A or P3, indicating little or no antigenic relationship.

Antiserum of P3 absorbed with D78, H-D, or H-E reacted strongly with antigens of D15A and P3 (Table 2, lines 14, 17, and 18), supporting the other reactions indicating the antigenic identity of P3 and D15A.

Antiserum H-D, absorbed by all the other organisms (Table 2, lines 20 through 24), gave no indication of an antigenic relationship with P3, D15A, or D78. A weak relationship was found between H-D and H-E.

Table 4.—Reaction of bacterial isolates to phages.

Isolate	Phage[a] 1	2	3	4	5	6	7
D78	–	–	–	–	–	–	–
D15A	+	+	+	+	+	+	+
D15	–	+	–	+	+	+	–
P3	+	+	+	+	+	+	+
H-D	–	+	+	+	–	–	+
H-E	–	–	–	–	–	–	–
Ps. fluorescens	–	–	–	–	–	–	–
Ps. mors-prunorum	–	–	–	–	–	–	–

[a] + indicates plaque formation; – indicates no plaque formation.

Finally, absorption of antiserum H-E with antigens of all the other isolates (Table 2, lines 26 through 30) indicated a weak antigenic relationship between H-E and D15A, P3, or H-D, and no relationship with D78.

In further tests, antiserum of D15A reacted with antigen of D15 (virulent parent) to give a titer of 1600, vs. the homologous titer of 3200. One isolate of *Ps. fluorescens* Migula (originally from Dr. P. Burkholder) and one of *Ps. mors-prunorum* Wormald (originally isolated by Dr. J. E. Crosse) showed no antigenic similarity to D78 or P3 in cross-agglutination tests.

Bacteriophagy.—The 7 phages isolated are described in Table 3.

Small turbid and large clear plaques were visible at 12–15 hours; large turbid plaques appeared at 24–48 hours. Secondary bacterial growth appeared readily inside the plaques produced by all phages except 6 and 7; plaques produced by the last two remained clear and with individual colonies only (Fig. 5). Type and size of plaques produced by the same phage on different isolates varied (Fig. 5), and none of the phages found were specific for a single bacterial isolate.

The reaction of bacterial isolates to phages and the relative plating efficiency of phage stocks are summarized in Tables 4 and 5.

Electronmicrographs from purified stocks revealed a similar morphology for phages 1, 3 and 7, although size, type of plaques, and host range were considerably different. Phages consisted of typical tailed particles with appendages; the hexagonal shape of the head was maintained in air-dried preparations (head 100 mμ wide, tail 150 mμ long and 30 mμ thick). At least 3 fibers were associated with the tail (Cf. Fig. 6).

Fig. 4.—Organism D15A agglutinated by antiserum of P3. From left to right: antiserum control; selected dilutions of 25, 100, 400, 800, and 3200; and antigen control.

Electronmicrographs of phages 2, 4, 5, and 6 were not clear enough for comparisons with the other phage preparations.

Discussion and conclusions.—*Pathogenicity.*—The bacterial isolates included in this study differed considerably in their pathogenicity or virulence on different hosts. Cells with different virulence were observed in the population of certain bacterial isolates, originally purified by dilution plate techniques, when single-cell derivatives were obtained. One single-cell derivative of isolate H-D proved more pathogenic on beans than the stock culture, whereas another single-cell derivative was avirulent. Isolate D15A, a single-cell derivative of D15, was less pathogenic on peach seedlings than its virulent parent. In contrast, pathogenicity of 10 single-cell derivatives of isolate P3 and 15 single-cell derivatives of isolate D78 was not significantly different from that of their stock cultures.

The search should be continued for a fast-growing host plant on which the infecting dose of bacterial cells could be accurately determined. Bean pods are a suitable material in this respect, but they are not reliable testers for stone fruit pathogens.

Serology.—Vennes and Gerhardt (26) made a comparative analysis of the major cell structures of *Bacillus megatherium* in a quantitative complement-fixation test. They reported that the injection of the intact cell stimulated the formation of antibodies to each of the component structures. Cell walls were the loci for the reactive surface antigens, and antibody globulin did not penetrate the cell wall.

Reid et al (21) could not differentiate serologically a great number of green-fluorescent pseudomonads, when live and killed entire cells were used as immunizing antigens.

In the present study a method of antigen preparation was adopted that detected slight differences between isolates of *Ps. syringae;* the immunizing antigen was prepared as previously described to stimulate the formation of antibodies to each of the antigenic components of the bacterial cell, comprising those associated with the cell wall structures as well as those of the inner cell.

Results of reciprocal agglutination absorption were in agreement with those suggested by cross-agglutination, and only isolates D15A and P3 were antigenically alike. There was either no agglutination for the other isolates, or agglutination only at low antiserum dilutions. These observations were supported by the unchanged titers after absorption.

These results indicate, among the isolates of *Ps. syringae* studied, a considerable degree of heterogeneity that would be difficult to reduce to a single serological group by antigenic analysis.

Organisms D15A and P3 fulfilled Krumwiede's

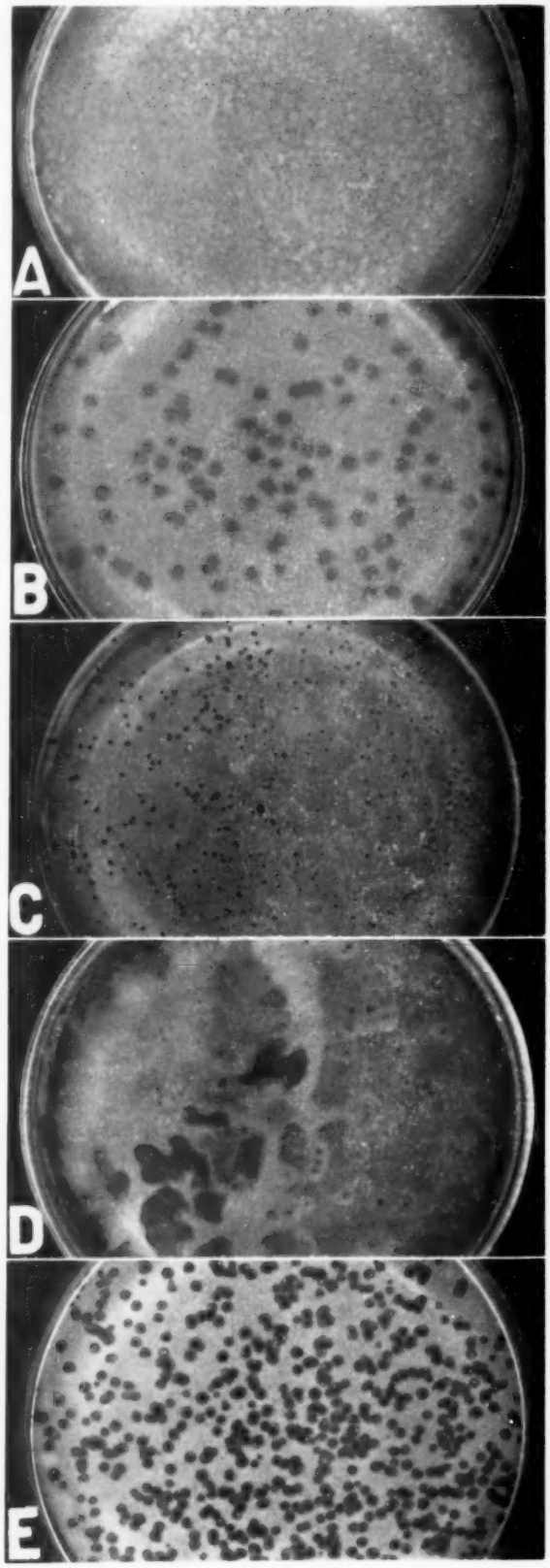


Fig. 5.—Morphology of plaques induced by phages on bacterial isolates. **A)** phage 1 on D15A; **B)** phage 2 on D15; **C)** phage 4 on P3; **D)** phage 4 on H-D; and **E)** phage 6 on P3.

Table 5.—Relative plating efficiency of phage preparations on 4 isolates of *Pseudomonas syringae*.[a]

Bacterial isolate	Phages						
	1	2	3	4	5	6	7
D15A	1.0×10^{7} (1.00)	2.0×10^{6} (0.50)	3.0×10^{10} (0.50)	1.2×10^{11} (0.92)	6.0×10^{5} (0.30)	4.0×10^{9} (0.60)	3.0×10^{10} (0.70)
D15	0	1.0×10^{7} (1.00)	0	2.7×10^{8} (<0.001)	1.0×10^{3} (<0.001)	1.0×10^{9} (0.14)	0
P3	1.0×10^{6} (0.10)	1.0×10^{6} (0.10)	6.0×10^{10} (1.00)	1.3×10^{11} (1.00)	2.0×10^{6} (1.00)	7.0×10^{9} (1.00)	4.0×10^{10} (1.00)
H-D	0	3.0×10^{6} (0.30)	4.0×10^{10} (0.66)	2.0×10^{10} (0.15)	0	0	1.0×10^{8} (0.002)

[a] First figures in each column indicate the observed number of plaques; figures between parentheses show the ratio $\frac{\text{plaque count on each isolate tested}}{\text{plaque count on homologous host}}$.

Plaque counts on homologous hosts are underscored.

postulate (16) of serological likeness or identity; a complete positive reciprocal agglutination absorption was observed in all tests. The two isolates appeared to be serologically identical although their pathogenicity differed strongly. The presence of serologically indistinguishable virulent and avirulent individuals in the same population was shown in this study. Pathogenicity was not associated with any particular antigenic type or structure.

Isolate H-E, which was avirulent on beans, showed a weak antigenic relationship to its original stock. Its identity, however, was not otherwise established. This avirulent isolate also showed very weak antigenic relationships with the other isolates. Reactions at only low antiserum dilutions in cross-agglutination and reciprocal absorptions led to the assumption that this isolate possesses some nonspecific antigen absent in the other isolates as certain combinations of agglutinins and cells gave negative reactions, whereas the reverse reactions were positive (lines 7, 13, and 25, Table 2).

Ps. fluorescens and *Ps. mors-prunorum*, a green-fluorescent nonpathogen and a nongreen-fluorescent pathogen, could not be related to the isolates with which they were tested. It is realized, however, that these two species also include many strains not available for comparison that might have reacted differently.

Isolate D78 showed a very weak antigenic relationship with D15A and P3, and little if any with both H-D and H-E.

Isolate H-D, which was characterized by a slimy growth and mucoid colonies, did not share any antigenic component with the other organisms tested. Strains antigenically identical in the "S" phase could differ serologically in the "M" phase (4). In this study, however, the preparation of the immunizing antigen should have removed any influence of the mucoid substance that did not block agglutination with homologous antiserum.

This study showed the feasibility of employing serological methods to distinguish different strains of *Ps. syringae* in the laboratory.

Bacteriophagy.—The phage-lysis technique used also indicated a high degree of variability and the existence of special forms within the species *Ps. syringae*.

Infection of bacteria with phages showed that isolates D15A and P3, antigenically alike, were consistently lysed by all phages. Response to phages varied in isolates D15 and H-D. Isolate H-D, which showed little if any antigenic relationship with the other isolates, was lysed by 4 phages, showing a common lytic reaction with isolates D15, D15A, and P3. Common surface antigens for positive agglutination on cells of isolate H-D were apparently not extensive; surface for the phage attachment was more commonly shared by the bacterial isolates.

Relative plating efficiency was highly variable. No phage was specific for any isolate, but variation was evident among the phages themselves.

If lysis of bacteria is taken as an indication of biological relationships, phages 2 and 4 would indicate similarity between four bacterial isolates: D15, D15A,

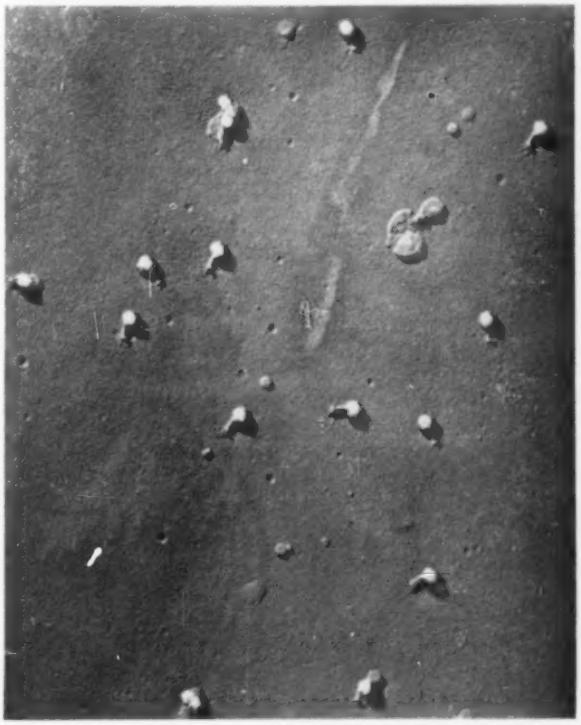


Fig. 6.—Electronmicrograph of a field of air-dry particles of phage 7 showing the hexagonal structure of the head. Fibers seem attached to a knot at the end of the tail. Uranium shadow 3:1, ×36,000.

P3 and H-D. Phages 3 and 7 would exclude isolate D15; phages 5 and 6 would differentiate isolate H-D, and phage 1 would separate isolates D15 and H-D.

It is expected that the isolation of more phages or selection of mutants would increase the range of this variation, and one phage endowed with a high degree of plasticity could lyse more or all isolates. A phage able to lyse numerous strains of 14 species of *Xanthomonas* was found by Sutton et al (25).

No phages were found for isolates D78, H-D, and H-E, but in this limited search phages with low virulence or slow absorption, or those that were lysogenic, may have been overlooked.

Isolates D78 and H-E were resistant to all phages tested. This condition alone does not exclude the possibility of any relationship, but lack of lysis in these two isolates was also in agreement with lack of agglutination in heterologous serological reactions.

Stocks of phages 1, 2, and 5 were never obtained in high titers and readily lost their infectivity. These phage preparations were maintained by frequent transfers from young plaques followed by incubation with their homologous bacterial isolates. These phages could have induced lysogenicity in the isolates from which they were isolated and have been reduced to prophages, which were responsible for the low titers of the stocks. When colonies growing inside turbid plaques induced by phage 1 were transferred to NB, new phage particles were liberated. The partially turbid culture, used as lysate, was useful for recovering this phage.

Phage sensitivity in the tests performed indicated a possible relationship between isolates D15, D15A, P3, and H-D. The limited number of phages tested, however, did not permit the selection of phages specific on bacterial isolates with certain characteristics such as pathogenicity, or of phages capable of lysing all isolates tested.

The phage study, although not strictly correlated with the serological analysis, proved of value as a preliminary test in obtaining information on relationships among bacterial isolates and eventually in reducing the number of isolates to be included in a more complete serological test.

The high degree of variability among isolates of *Ps. syringae* and among their phages from different geographical areas should receive careful consideration before emphasizing differences such as infectivity on a particular host or lysis by a certain phage. Bacterial isolates from one area may become adapted to a new host as a consequence of greater variability or broader specialization; similarly one particular phage may infect more bacterial isolates than another because of the variability within the strains of phages. The difficulty of covering the full range of variability among bacterial and phage strains from different areas is realized. A range of variability must be expected in standard tests on the basis of fine cytoplasmic and somatic differences that do not allow the reduction of highly specialized biological forms to one single group.—Department of Plant Pathology, University of California, Davis.

LITERATURE CITED

1. Adams, M. H. 1956. Methods of study of bacterial viruses. Methods in Med. Research Vol. 2 Sect. 1:1-73.
2. Baker, K. F. 1957. The U. C. system for producing healthy container-grown plants. Calif. Univ. Agr. Expt. Sta. Ext. Serv. Manual 23.
3. Clara, F. 1934. A comparative study of the green-fluorescent bacterial plant pathogens. Cornell Univ. Agr. Expt. Sta. Mem. 159.
4. Coleman, Madeline, and J. J. Reid. 1945. A serological study of strains of Alcaligenes radiobacter and Phytomonas tumefaciens in the M and S phases. J. Bacteriol. 49:187-192.
5. Crosse, J. E. 1953. Bacterial diseases of stone-fruit trees in Britain. IX. Bacteriosis of apricot. Brit. Mycol. Soc. Trans. 36:38-45.
6. Crosse, J. E. 1954. Bacterial canker, leaf spot, and shoot wilt of cherry and plum. Ann. Rept. East Malling Research Sta. 1953:202-207.
7. Crosse, J. E. 1959. Plant pathogenic bacteria and their phages. Commonwealth Phytopathol. News Vol. 5: 17-19.
8. Dowson, W. J. 1939. On the systematic position and generic names of the gram-negative bacterial plant pathogens. Zentr. Bakteriol. Parasitenk. Abt. II 100:177-193.
9. Dye, D. W. 1954. Blast of stone-fruit in New Zealand. New Zealand J. Sci. Technol. 35A:451-461.
10. Erikson, Dagny. 1945. Certain aspects of resistance of plum trees to bacterial canker. I. Some biochemical characteristics of Pseudomonas mors-prunorum and related phytopathogenic bacteria. Ann. Appl. Biol. 32:44-52.
11. Friedman, B. A. 1953. Serological tests with some phytopathogenic species. Phytopathology 43:412-414.
12. Fuchs, A. 1957. Bacteriekanker bij Steenvruchten. II. De Identiteit van Pseudomonas mors-prunorum Wormald en Pseudomonas syringae Van Hall. (English summary). T. Pl. ziekten 63:45-57.
13. Fulton, R. W. 1950 Bacteriophages attacking Pseudomonas tabaci and P. angulatum. Phytopathology 40:936-949.
14. Katznelson, H., and M. D. Sutton. 1951. A rapid phage plaque count method for the detection of bacteria as applied to the demonstration of internally borne bacterial infections of seeds. J. Bacteriol. 61:689-701.
15. Klement, Z., and Mary Hevesi. 1959. Occurrence of Pseudomonas lachrymans in Hungary and Rumania and its bacteriophage. Research Institute for Plant Protection Budapest. Omagiu Lui Traian Savulescu CU PRILEJUL IMPLINIRII A 70 DE ANI.
16. Krumwiede, C., Georgia Cooper, and Dorothy Provost. 1925. Agglutinin absorption. J. Immunol. 10:55-239.
17. Lederberg, J. 1954. A simple method for isolating individual microbes. J. Bacteriol. 68:258-259.
18. Matsumoto, T., and N. Okabe. 1935. Bacteriophage in relation to Bacterium solanacearum. I. Temperature relation, specificity and serological reaction. J. Soc. Trop. Agr. 7:130-139. (Abstr. Rev. Appl. Mycol. 14:686, 1935).
19. Munoz, J., M. Scherago, and R. H. Weaver. 1949. A serological study of members of the Pseudomonas genus. J. Bacteriol. 57:269-278.
20. Mushin, Rose, J. Naylor, and N. Lahovary. 1959. Studies of plant pathogenic bacteria. I. Cultural and biochemical characters. II. Serology. Australian J. Biol. Sci. 12:223-246.
21. Reid, J. J., J. Naghski, M. A. Farrell, and D. E. Haley. 1942. Bacterial leafspots of Pennsylvania tobacco. Occurrence and nature of the microorganism associated with wildfire. Penna. State Coll. Agr. Expt. Sta. Bull. 422.
22. Rhodes, Muriel E. 1959. The characterization of Pseudomonas fluorescens. J. Gen. Microbiol. 21:221-263.
23. Rosen, H. R., and W. L. Bleecker. 1933. Comparative serological and pathological investigations of the fire-blight organism and a pathogenic fluorescent group of bacteria. J. Agr. Research 46:95-119.

24. Society of American Bacteriologists, Committee on Bacteriological Technic. 1957. Manual of Microbiological Methods. McGraw-Hill Book Co. 315 p.
25. Sutton, M. D., H. Katznelson, and C. Quadling. 1958. A bacteriophage that attacks numerous phytopathogenic Xanthomonas species. Can. J. Microbiol. 4:493-497.
26. Vennes, J. W., and P. Gerhardt. 1959. Antigenic analysis of cell structures isolated from Bacillus megatherium. J. Bacteriol. 77: 581-592.
27. Williams, R. C., and D. Fraser. 1953. Morphology of the seven T-bacteriophages. J. Bacteriol. 66:458-464.
28. Wilson, E. E. 1931. A comparison of Pseudomonas prunicola with a canker-producing bacterium of stone-fruit trees in California. Phytopathology 21: 1153-1161.
29. Wilson, E. E. 1933. Bacterial canker of stone-fruit trees in California. Hilgardia 8:83-123.
30. Wilson, E. E. 1934. Variability of Pseudomonas cerasi in physical characteristics of growth on solid media. Phytopathology 24:548-550.
31. Wilson, E. E. 1936. Symptomatic and etiological relations of the canker and the blossom blast of Pyrus and the bacterial canker of Prunus. Hilgardia 10:213-240.
32. Wilson, E. E. 1953. Bacterial canker of stone fruits. U.S.Dept. Agr. Yearbook on Plant Diseases. p. 722-729.
33. Wormald, H. 1930. Bacterial diseases of stone fruits in Britain. Bacterial shoot wilt of plum trees. Ann. Appl. Biol. 17:725-744.
34. Wormald, H. 1932. Bacterial diseases of stone-fruit trees in Britain. IV. The organism causing bacterial canker of plum trees. Brit. Mycol. Soc. Trans. 17:157-169.

THE BLACK SHANK-ROOT-KNOT COMPLEX IN FLUE-CURED TOBACCO

N. T. Powell and C. J. Nusbaum

Respectively, Research Assistant Professor and Professor, Department of Plant Pathology, North Carolina State College, Raleigh.

Accepted for publication July 5, 1960.

Published with approval of the Director as Paper No. 1167 of the Journal Series of the North Carolina Agricultural Experiment Station.

The authors are indebted to Dr. E. L. Moore for valuable advice and assistance on the hybridization phases of the investigations.

SUMMARY

Resistance to *Meloidogyne incognita incognita* and *M. incognita acrita* was incorporated into black-shank-resistant tobacco varieties Dixie Bright 101 and Coker 139 by a backcross procedure. The recurrent parents and root-knot-susceptible and -resistant segregates of backcross progenies were inoculated with the black shank fungus alone and in combination with *M. incognita acrita*. Black shank was much more severe among plants of the recurrent parents in the presence of both pathogens than among plants inoculated with the fungus alone. Similarly, the incidence of black shank was significantly higher among root-knot-susceptible segregates inoculated with both pathogens than among root-knot-resistant segregates under the same conditions. There were no appreciable differences in black shank development between root-knot-susceptible and -resistant segregates when inoculated with the fungus alone.

Root infections involving both the black shank fungus and root-knot nematodes were studied histologically. The fungus apparently had an affinity for hypertrophied and hyperplastic areas of galled root tissue. In such regions, the mycelium was more extensive and vigorous than in nongalled areas. Hyphae progressed rapidly and directly into hyperplastic tissue and giant cells. After fungus invasion, a compatible relationship apparently existed between pathogen and host cells undergoing hyperplasia. Giant cells, although conducive to fungus invasion, seemed highly sensitive to infection. They degenerated rapidly and, within 72 hours of fungus invasion, appeared completely devoid of protoplasm. Histopathological observations indicated that root-knot nematode infection predisposes plants to black shank invasion, to the extent that roots of black-shank-resistant and -susceptible plants become a suitable substrate for fungus development.

Several kinds of soil-borne microorganisms, including species of fungi, bacteria, and nematodes, are causal agents of the most important diseases of flue-cured tobacco in North Carolina. Each disease is distinctive, but the over-all disease situation is complex because two or more pathogens may overlap at varying infestation levels. Hence, disease control requires an understanding, not only of the behavior of each disease individually, but also of various combinations of diseases. This paper is concerned with an important complex involving two of the most widespread and destructive tobacco diseases, black shank, caused by *Phytophthora parasitica* var. *nicotianae* (Breda de Haan) Tucker, and root knot, caused by nematodes of several species of the genus *Meloidogyne*, Goeldi.

Following pioneer work by Tisdale (13) in developing black-shank-resistant varieties of cigar wrapper tobacco, breeding for resistance has become the basis for control programs in North Carolina and other areas. Florida 301, Tisdale's original resistant variety, is the source of resistance in the black-shank-resistant varieties of flue-cured tobacco now in use.

Lacking resistant varieties, the root-knot nematode control program is based on various cropping systems (3), cultural practices, and nematocidal soil fumigants (8). Certain cropping systems are effective in reducing root-knot nematode populations, but control by this means is often difficult and uncertain. Rotations involving two or more resistant crops between tobacco crops are desirable, but involve much land area, often a critical consideration in flue-cured tobacco culture.

Clayton et al (2) initiated breeding work in tobacco on resistance to root-knot nematodes using as a source of resistance TI 706 (accession number of the Tobacco Section, U. S. Department of Agriculture, referring to Plant Introduction 116,080). However, resistance was closely linked with factors for undesirable characters. To break this linkage, a root-knot-resistant line resulting from backcrossing TI 706 and flue-cured tobacco was crossed with the amphidiploid, *Nicotiana sylvestris-tomentosiformis*. This cross yielded some lines highly resistant to root knot and devoid of the characters formerly associated with resistance. These lines possessed dominant monogenic resistance to *M.*

incognita incognita and *M. incognita acrita* (4). All species of *Meloidogyne* known to occur in North Carolina are pathogenic on tobacco, but only the above species are important pathogens of this crop at present (11).

Tisdale (13) called attention to the relationship between black shank and root knot when he observed that resistance to black shank in certain tobacco breeding lines was reduced in the presence of root-knot nematodes. Moore and co-workers (5) noted a similar relationship. Also, black shank is less severe in resistant varieties when preplant treatments of nematocides are applied to fields infested with both pathogens (7). Greenhouse tests by Sasser, Lucas, and Powers (12) demonstrated that black shank was invariably more severe when soils were infested with both pathogens than when only the black shank fungus was present. These observations and studies indicate that interaction between the fungus and root-knot nematodes may be involved when losses to black shank are heavy in plantings of varieties resistant to this disease.

The availability of root-knot nematode resistance in tobacco provides a new approach to study the interaction between the black shank fungus and root-knot nematodes. Experiments were designed to determine 1) the effect of incorporating root-knot resistance into black-shank-resistant lines and the response of these lines to black shank in the presence of root-knot nematodes, and 2) the nature of the black shank-root-knot relationship in roots infected with both pathogens. To achieve the first objective, black shank infection was measured in both root-knot-inoculated and root-knot-free plants of both root-knot-resistant and -susceptible segregates from backcross lines carrying resistance to black shank. The black-shank-resistant root-knot-susceptible recurrent parents were included as checks. Information on the second objective was obtained from a comparative histopathological study of the invasion of root-knot galls and healthy roots by the black shank fungus. A preliminary report has been published (9).

Materials and methods.—A backcross technique was used to incorporate resistance to *M. incognita incognita* and *M. incognita acrita* into commercial black-shank-resistant varieties. Two breeding lines, Bel 4-30 and Bel 5-56, obtained from the U. S. D. A., were sources of root-knot resistance, and the black-shank-resistant varieties Dixie Bright 101 and Coker 139 were the recurrent male parents. Segregating populations were selected for root-knot resistance, and only resistant individuals were used as female parents. Thus, there were two families of plants: Dixie Bright 101 × Bel 5-56 and Coker 139 × Bel 4-30. The two families were carried through 2 and 3 backcross generations, respectively.

Two hundred plants from each of the BC_1 and BC_2 generations of the Dixie Bright 101 family and from the BC_2 and BC_3 generations of the Coker 139 family were transplanted singly into 4-in. clay pots containing soil heavily infested with eggs and larvae of *M. incognita acrita*, and allowed to grow for 30 days in the greenhouse at about 80°F. The roots were then examined for galls, and classified as susceptible or resistant. A terminal vegetative cutting was taken from each plant when classified for root-knot reaction, treated with Rootone (active ingredient, indoleacetic acid), and rooted in flats of steam-sterilized coarse sand.

Rooted cuttings from both root-knot-resistant and -susceptible plants were further subdivided into 2 groups of 20 plants each. One group each of resistant and susceptible segregates was planted in 4-in. clay pots of steamed soil artificially infested with eggs and larvae of *M. incognita acrita*, and one group of each class was planted in pots of steamed soil to which no nematodes were added.

M. incognita acrita was grown on susceptible tobacco and tomato plants, and the chopped roots and the soil in which they were grown were the inoculum. The inoculum was mixed 1:20 with steamed potting soil.

Two isolates of the fungus, obtained from Dr. J. L. Apple, were cultured for 4 weeks on sterilized whole oat grains. One-hundred-gram portions of the oat cultures were blended for about 20 seconds with 200 ml of tap water in a Waring blender. This was added to an additional 1000 ml of tap water, and the resulting mixture was used as inoculum. Equal parts of each fungus isolate were included in the inoculum mixture.

Six weeks after repotting, all plants were inoculated with the black shank fungus in a manner that prevented any inoculum from contacting the tap root or basal portion of the stalk. Openings about 2 in. from the plant stem were forced into the soil in each pot with a garden stake. Forty-eight hours later, 60 ml of inoculum were poured into the openings in each pot. The black-shank-resistant recurrent parents received the same treatments. The number of dead plants within each group was recorded 30 days after inoculation with the black shank fungus.

Plant material for histological studies was prepared from roots of root-knot-susceptible plants. Roots of plants about 12 in. tall were washed, and entire plants were placed in moist chambers. The root tips were covered with a layer of moist fine sand. Larvae of *M. incognita acrita*, obtained by the Baermann funnel technique (1), were introduced onto the layer of sand. Zoospores of the black shank fungus were placed at the same location 48 hours later. Specimens were collected from this material 36 hours after fungus inoculation.

Additional root-knot-susceptible plants were grown in soil infested with *M. incognita acrita* until galls were well developed. The galled roots were washed, and entire plants were placed in moist chambers lined with moist absorbent paper. Zoospores of *P. parasitica* var. *nicotianae* were placed directly on galls in various stages of development. Galled root specimens were

Table 1.—Influence of root knot on black shank development among plants of the recurrent parent varieties.

Variety	Percentage of plants dead 3 weeks after inoculation with *P. parasitica* var. *nicotianae*[a]	
	I[b]	N[b]
Dixie Bright 101	100	40
Coker 139	95	40
Significance for nematode inoculation[c]	**	
Significance for varieties	NS	
Inoculation × varieties	NS	

[a] 20 plants of each parent were included in each treatment.
[b] I, inoculated with *M. incognita acrita*; N, no nematode inoculation.
[c] NS, nonsignificant; **, significant at 1% level.

collected 36, 48, and 72 hours after fungus inoculation.

Cultures of *P. parasitica* var. *nicotianae* for use as inoculum in the histological studies were grown at room temperature on oatmeal agar until the colonies covered a 9-cm Petri dish and abundant aerial mycelium was present. The aerial mycelium was stripped from the cultures and transferred to 4.5-cm Petri dishes containing about 6 ml of distilled water. These preparations were incubated 3 days at 28°C, by which time mature zoosporangia were abundant. Zoospore discharge was induced by chilling.

The root specimens were fixed in formal-acetic- alcohol, dehydrated with an ethanol and tertiary-butyl-alcohol series, infiltrated with paraffin, and embedded in tissuemat (10). Sections 10 μ thick were cut with a rotary microtome and stained with safranin and fast green.

Experimental results.—*Inoculation studies.*—Initially, plants of the recurrent parents and backcross progenies inoculated with *M. incognita acrita* were severely stunted, chlorotic, and weak. After about 14 days, however, resistant plants began to overcome the initial reduction in vigor, and they were green and vigorous within 30 days of inoculation. Their root systems were free from galls. Susceptible plants, however, remained stunted, and their roots were severely galled.

Inoculation of the recurrent parents with the black shank fungus alone and following inoculation with *M. incognita acrita* resulted in well defined differences in black shank incidence. In all tests, Dixie Bright 101 and Coker 139 plants developed black shank much more rapidly and extensively when nematodes were also present (Table 1; Fig. 1).

There were no appreciable differences in black shank development between root-knot-resistant and -susceptible segregates of any backcross progeny when root-knot nematodes were absent (Table 2). In the presence of both pathogens, however, there were strik-

Fig. 1.—Recurrent parent, Coker 139. The plants on the left were grown in soil inoculated with the black shank fungus and root-knot nematodes; the plants on the right were grown in soil inoculated with the black shank fungus only.

Table 2.—Influence of root knot on black shank development among segregating backcross progenies.

	% of plants dead 3 weeks after inoculation with *P. parasitica* var. *nicotianae*[a]							
	DB 101 family				C 139 family			
	BC_1F_1		BC_2F_1		BC_1F_1		BC_2F_1	
	I[b]	N	I	N	I	N	I	N
Root-knot-resistant	35	60	20	45	30	25	25	30
Root-knot-susceptible	95	50	90	35	70	30	75	20
Significance for nematode inoculation	NS[c]		*		**		**	
Significance for genotype	**		**		**		**	
Inoculation × genotype	**		**		*		**	

[a] 20 plants of each backcross progeny were included in each treatment.
[b] I, inoculated with *M. incognita acrita*; N, no nematode inoculation.
[c] NS, nonsignificant; *, significant at 5% level; **, significant at 1% level.

ing differences in the incidence of black shank between root-knot-susceptible and -resistant individuals. In all backcross progenies, black shank incidence was much greater in groups of root-knot-susceptible segregates than in groups of root-knot-resistant segregates. In addition, black shank developed much faster among root-knot-susceptible segregates than among resistant individuals.

Histological studies.—Roots of root-knot-susceptible plants were inoculated with the black shank fungus 48 hours after inoculation with nematode larvae to determine whether nematode entry enhances penetration and colonization of the host by the fungus. In material fixed 36 hours after fungus inoculation, a number of larvae had penetrated the root and, in some cases, had nearly reached the stele. The fungus had also entered, and it had colonized tissue extending from the epidermis to approximately the third layer of cortical cells. The fungus mycelium appeared relatively vigorous, and there was slight reaction by the host to fungus invasion. This reaction was exemplified primarily by suberization of the cortical cell walls contiguous to invaded cells.

Fungus penetration appeared to be slightly more extensive in areas of recent nematode entry than in regions some distance from nematode infection, although no cases were noted in which the fungus hyphae actually followed the avenues provided by the larvae. Similarly, the fungus in close proximity to regions of nematode invasion may have ingressed slightly further into cortical cells than had the fungus in areas not near points of nematode entry. Such differences, however, were difficult to perceive.

The root anatomy, in sections cut through galls formed by the root-knot nematode, was characterized by regions of hyperplasia and hypertrophy. Hyperplastic areas usually surrounded the locus of nematode infection and were evidenced by masses of small cells densely filled with protoplasm. Hypertrophied cells were in the form of nectaries or giant cells filled with a fine reticulate network of protoplasm and containing many giant nuclei. The head region of the enlarged female nematode was often observed in the vicinity of the giant cells.

The fungus had moderately colonized nongalled root tissue after 36 hours. Epidermal penetration occurred by means of germinating zoospores, and was followed by mycelial invasion of cortical cells.

Invasion and colonization was strikingly more extensive in galled tissue than in nongalled areas. In such tissue, the fungus was present in abundance in the stele as well as in the cortex. In certain instances, fungus hyphae were apparently progressing directly through cortical cells into hyperplastic and hypertrophied tissue (Fig. 2-B), resulting in a preponderance of mycelium in these areas. The fungus mycelium occupying galled tissue appeared very robust and vigorous. The hyphae were larger than those in nongalled areas and were densely filled with protoplasm. The nuclei of the fungus were clearly visible.

Host reaction was rather slight to fungus invasion of root-knot-galled tissue in hyperplastic areas. There was suberization of cortical cell walls in regions near fungus infections, but hyphae penetrated these altered walls. By contrast, granular degeneration of giant cell protoplasts commenced soon after invasion by the fungus hyphae. The giant nuclei disappeared and the protoplasm became dense, granular, and shriveled (Fig. 2-A).

The pattern of pathogenesis in galled roots fixed 48 and 72 hours after fungus inoculation was similar to that in material fixed 36 hours after inoculation. The entire process was more advanced in the material fixed later. Large, vigorous, dense hyphae were clearly evident, especially in hyperplastic and hypertrophied tissue. In many instances, the hyphae completely filled the cell lumen. At 48 hours, giant cells contained reduced amounts of protoplasm (Fig. 2-C), and at 72

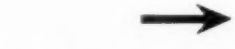
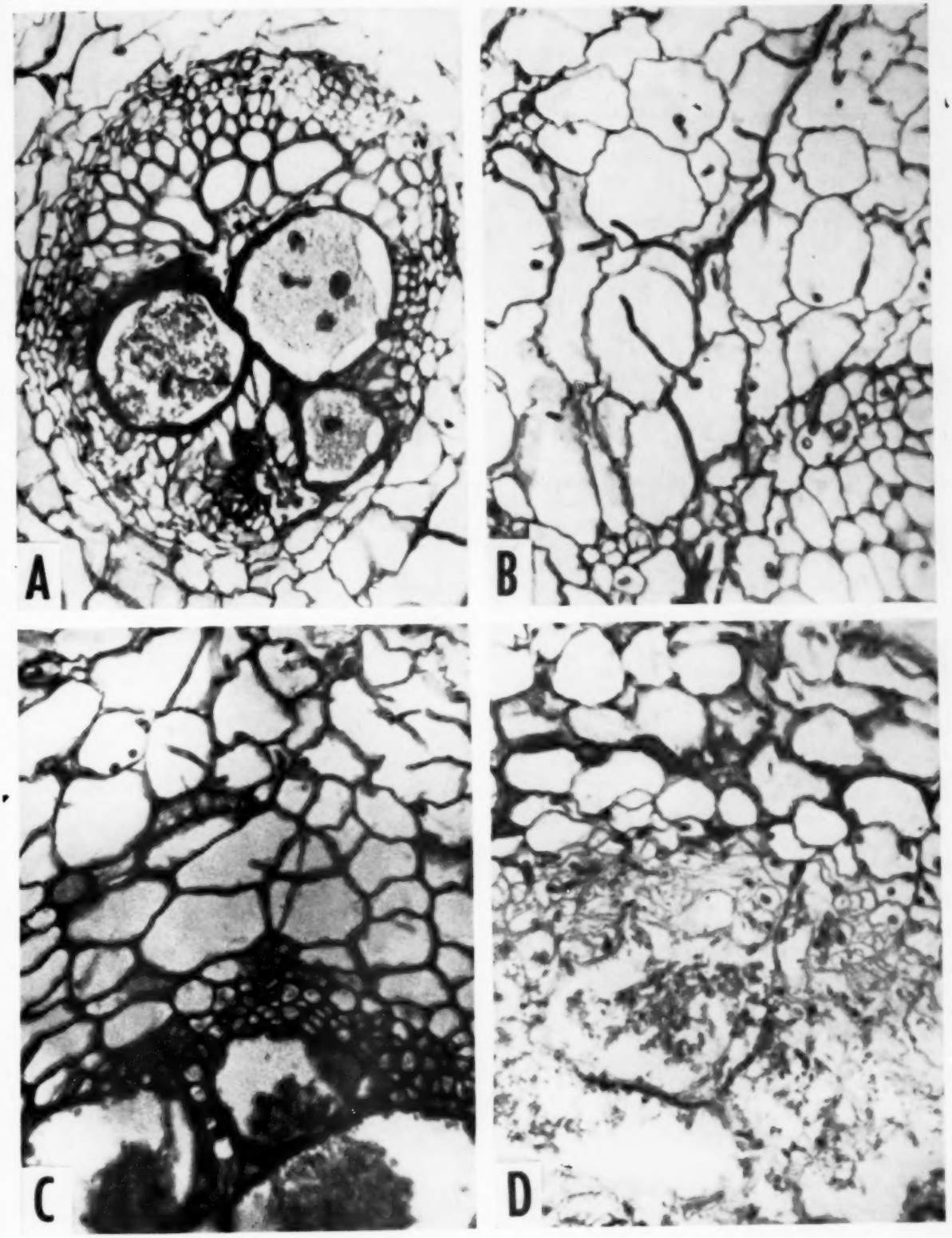


Fig. 2.—Cross sections of galled tobacco roots. **A)** 36 hours after inoculation with the black shank fungus. The fungus has entered the giant cell on the left and extends into the degenerating protoplast. The remaining giant cells are not infected. **B)** 36 hours after fungus inoculation. The hyphae are progressing directly through the cortex and into hyperplastic regions. There is little apparent reaction to fungus invasion. **C)** 48 hours after fungus inoculation. The hyphae have progressed into hypertrophied tissue. Giant cell protoplasts are degenerating. **D)** 72 hours after fungus inoculation. Degenerate giant cells are occupied by weakened fungus hyphae.


A
B
C
D

hours they were completely devoid of this substance (Fig. 2-D, 3-A). Giant cell walls appeared less rigid.

Hyphae occupying giant cells that were devoid of protoplasm were smaller and absorbed less stain, and in some cases had begun to shrivel (Fig. 2-D).

Some specimens were observed in which the female nematode had attained maturity and had produced egg masses that protruded through the cortex and epidermis of the root. Robust hyphae of the fungus readily penetrated and ramified through epidermal and cortical regions immediately adjacent to such nematodes, and colonization of these regions was extensive (Fig. 3-B,C). Fungus hyphae were frequently noted within the gelatinous matrix of the egg mass (Fig. 3-D).

Discussion.—The final backcross to Dixie Bright 101 (DB 101 BC_2) resulted from 3 crosses to the recurrent parent. Theoretically, the genotype of this backcross progeny should be about 87.5% that of Dixie Bright 101. This value, of course, is applicable only to the characters for which selection was not exercised. Comparisons in phenotype between backcross progeny and the recurrent parent consisted only of visual observations. The two groups of plants resembled each other in most respects. The phenotypic differences, however, were sufficient in number and magnitude to show that 3 crosses to Dixie Bright 101 were inadequate to regain the phenotype of the recurrent parent. Even so, this goal was approached, and it is believed that 2 or 3 additional crosses to Dixie Bright 101 would result in progeny having essentially the same phenotype as Dixie Bright 101, assuming that no pleiotropic effects or close linkages exist.

The same general conclusions may be made regarding Coker 139 and its final backcross progeny, C139 BC_3. One more backcross was made with Coker 139 than with Dixie Bright 101, but the progeny of the former, although resembling Coker 139, still differed from it in enough respects to indicate that the backcross program had not progressed far enough to yield a "root-knot-resistant Coker 139."

Inoculation of the recurrent parents, Coker 139 and Dixie Bright 101, with the black shank fungus alone and in combination with root-knot nematodes confirms the conclusion that the black shank disease is much more severe when nematodes are present (12). The incidence of black shank was higher among plants previously inoculated with root-knot nematodes (Table 1). The same effect was clearly illustrated by the differences in black shank development between root-knot-resistant and -susceptible segregates of backcross progeny when inoculated with both pathogens (Table 2). The disease was much more severe among the root-knot-susceptible individuals. In the root-knot-resistant class of the DB 101 family, there is an abnormally high percentage of dead plants among those not inoculated with nematodes (Table 2). The reason may be that the resistant and susceptible classes were both stunted immediately after nematode inoculation but that the resistant plants overcame this effect. Thus, the roots of plants of the latter class had opportunities to grow downward into contact with the fungus inoculum (placed near the lower portion of the rhizosphere). In the absence of nematodes there were no appreciable differences between root-knot-resistant and -susceptible segregates in black shank development. This indicates that no differences in genetic factors for black-shank resistance exist between these two groups of plants; hence, the greater incidence of the disease among root-knot-susceptible plants than among -resistant plants in the presence of nematodes must be due to nematode infection.

These findings could explain, in many cases, the apparent "breakdown" of resistance often noted with black-shank-resistant varieties. Many fields planted to black-shank-resistant varieties are infested with root-knot nematodes in addition to *P. parasitica* var. *nicotianae*. The inoculation experiments reported herein show that, under such conditions, the incidence of black shank may be extremely high, even in resistant varieties (Table 1). Hence, black-shank-resistant varieties may not give adequate control of this disease in soils infested with both pathogens. This fact is of paramount importance in North Carolina because root-knot nematodes are present in most of the state's tobacco-producing areas. Varieties with resistance to both pathogens would protect against losses not only from each but also from the more hazardous complex of both diseases.

The nature of the relationship between the host plant and the two pathogens is of special interest. Sasser and co-workers (12) concluded that the wounding action by the nematodes was not responsible for increased black-shank severity. This factor has been considered of prime importance in certain other disease interactions involving the root-knot nematode. It is well known, however, that the black shank fungus can directly penetrate roots of both susceptible and resistant plants and establish a pathogenic relationship with the host in a very short period (6). It seems, therefore, that wounding would not be of major importance in the black shank-root-knot interaction.

The histological observations indicate that wounding of the root by the nematode probably plays only a minor role, if any, in the black shank-root-knot complex. Even though the fungus may have penetrated slightly faster and more extensively in areas surrounding recent nematode larvae penetration sites than in regions farther removed from points of larvae entry, these differences did not seem great enough to contribute appreciably to the interaction.

The behavior of the fungus within root-knot galls is considered significant. The fungus thrived on hyperplastic and hypertrophied root tissue. Hyphae appeared to grow directly into such regions, and colonization was rapid and extensive. The mycelium that occupied galled tissue appeared extremely vigorous: the hyphae were large and densely filled with protoplasm, and contained conspicuous nuclei.

Fungus colonization was extensive in areas surrounding female nematodes. Mycelium was often observed within an egg mass. It is believed that such regions

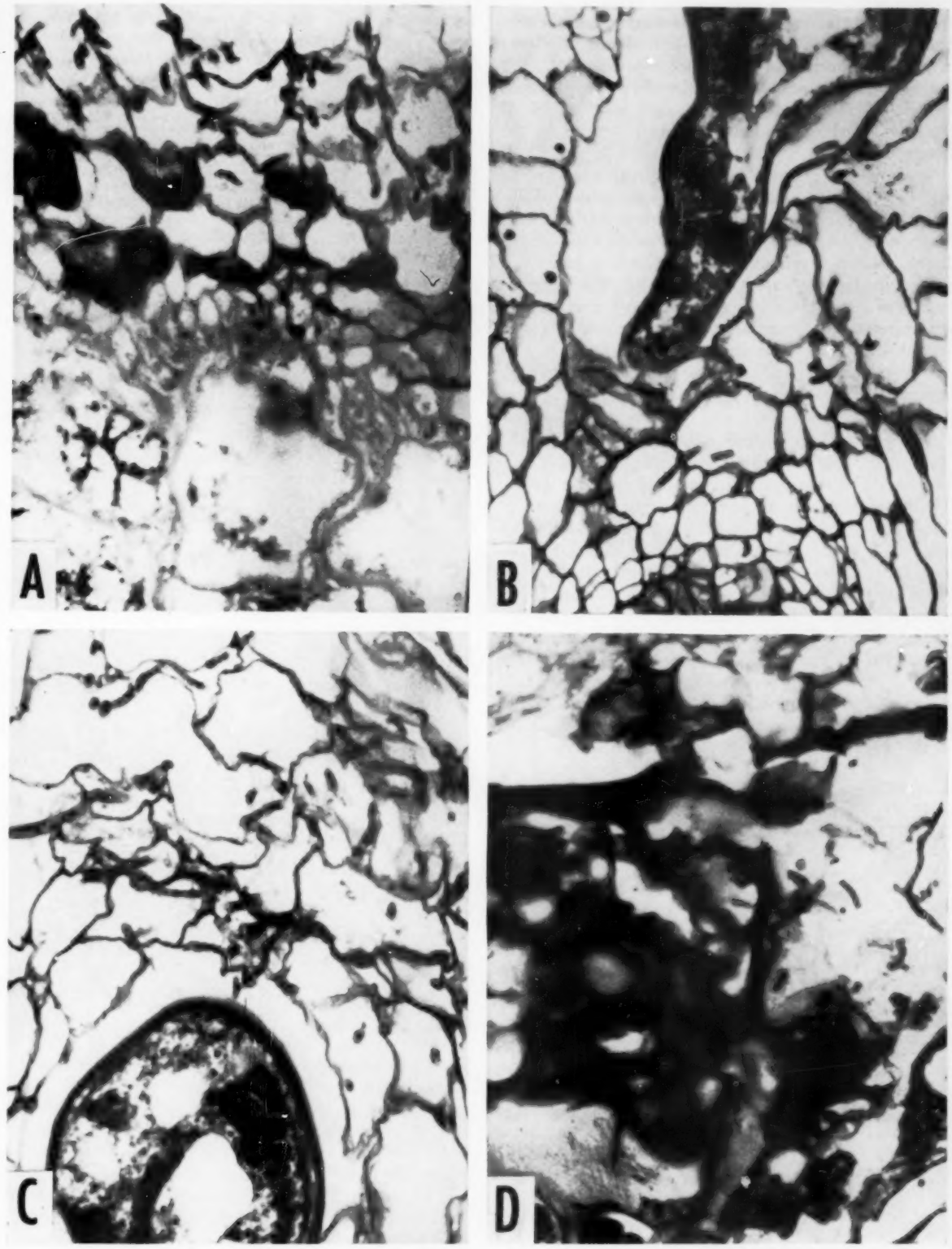


Fig. 3.—Cross sections of galled tobacco roots. **A)** 72 hours after fungus inoculation. There is extensive fungus colonization in hyperplastic tissue, and giant cells have degenerated completely. **B)** The fungus is colonizing tissue surrounding the anterior portion of the female nematode. **C)** The fungus is colonizing tissue surrounding the posterior portion of the nematode. **D)** The fungus is growing within a nematode egg mass.

are very conducive to fungus invasion, and thereby promote increased severity of black shank infections in plants harboring an abundance of nematodes. The fungus did not appear to parasitize the nematode eggs, but the gelatinous mass in which eggs were embedded evidently provided a suitable growth substrate for the fungus.

None of the galled tissue was resistant to fungus invasion; in fact, a congenial relationship existed between host and parasite in most hyperplastic tissue. Giant cells, however, were quite sensitive to fungus attack. When the hyphae first entered, a giant cell started to undergo rapid degeneration. The degeneration was characterized by the dense and granular appearance of the giant cell protoplast. This was succeeded by rapid disappearance of protoplasm. As degeneration progressed, hyphae within the giant cells appeared less vigorous.

Regardless of giant-cell reaction, the extensive colonization of gall tissue, the robust appearance of the fungus, and the congenial host-parasite relations exhibited under these conditions indicate that galled tobacco root affords an ideal substrate for growth of the black shank fungus, and the fungus exhibits an affinity for such tissue. On the basis of these histopathological observations, it is believed that the relationship herein described contributes to a better understanding of the "black shank-root-knot interaction." Nematode infection predisposes the plant to such an extent that the root tissue of black-shank-resistant and -susceptible varieties becomes suitable for fungus invasion and colonization. Thus, the basis of the interaction lies not in the direct effect of either pathogen on the other, but on the effect of the nematode on the host and the subsequent effect of the fungus on the modified host tissue. The host plant is an integral part of the interaction. Just what biochemical and physiological changes occur in galled tissues to make them so favorable for the growth of the black shank fungus awaits further research.

LITERATURE CITED

1. Christie, J. R., and V. G. Perry. 1951. Removing nematodes from soil. Proc. Helminthol. Soc. Wash. D. C. 18:106-108.

2. Clayton, E. E., T. W. Graham, F. A. Todd, J. G. Gaines, and F. A. Clark. 1958. Resistance to the root knot disease of tobacco. Tobacco Science 2:53-63.

3. Clayton, E. E., J. G. Gaines, T. E. Smith, K. J. Shaw, and T. W. Graham. 1944. Control of flue-cured tobacco root diseases by crop rotation. U. S. Dept. Agr. Farmers' Bull. 1952. 12 p.

4. Drolsom, P. N., E. L. Moore, and T. W. Graham. 1958. Inheritance of resistance to root-knot nematodes in tobacco. Phytopathology 48:686-689.

5. Moore, E. L., P. N. Drolsom, F. A. Todd, and E. E. Clayton. 1956. Black shank resistance in flue-cured tobacco as influenced by tolerance to certain parasitic nematodes. Phytopathology 46:545-550.

6. Nusbaum, C. J. 1952. Host-parasite relations of Phytophthora parasitica var. nicotianae in roots of resistant and susceptible tobacco varieties. (Abstr.). Phytopathology 42: 286.

7. Nusbaum, C. J., and J. F. Chaplin. 1952. Reduction of the incidence of black shank in resistant tobacco varieties by soil fumigation. (Abstr.). Phytopathology 42:15.

8. Nusbaum, C. J., and F. A. Todd. 1957. Evaluation of chemical soil treatments for nematode control in plant bed demonstration tests—1956. Plant Pathology Information Note No. 42. N. C. State College, Raleigh, N. C.

9. Powell, N. T., and C. J. Nusbaum. 1958. The effect of root-knot nematode resistance on the incidence of black shank in tobacco. (Abstr.). Phytopathology 48:344.

10. Sass, J. E. 1940. Elements of botanical microtechnique. McGraw-Hill Book Co., Inc., New York, N. Y.

11. Sasser, J. N. 1954. Identification and host-parasite relationships of certain root-knot nematodes (Meloidogyne spp.). Maryland Univ. Agr. Expt. Sta. Tech. Bull. A-77. 30 p.

12. Sasser, J. N., G. B. Lucas, and H. R. Powers, Jr. 1955. The relationship of root-knot nematodes to black shank resistance in tobacco. Phytopathology 45:459-461.

13. Tisdale, W. B. 1931. Development of strains of cigar wrapper tobacco resistant to black shank (Phytophthora nicotianae Breda de Haan). Florida Univ. Agri. Expt. Sta. (Gainesville). Bull. 226. 45 p.

BACTERIAL STRIPE OF CORN

A. J. Ullstrup

Plant Pathologist, Department of Botany and Plant Pathology, Purdue University, Lafayette, Indiana, and Crops Research Division, ARS, U.S.D.A.

Cooperative investigation, Purdue Agricultural Experiment Station, and Crops Research Division, ARS, U.S.D.A. Journal Paper No. 1603 of the Purdue Agricultural Experiment Station.

Accepted for publication July 5, 1960.

SUMMARY

Bacterial stripe, an unreported naturally occurring disease of corn, appears to be incited by *Pseudomonas andropogonis*, the pathogen responsible for bacterial stripe of *Sorghum* spp. This conclusion is based on cross-inoculation studies and a comparison of morphological, cultural, and physiological characters of isolates from corn infected with *P. andropogonis*. The unusual and conspicuous secondary symptoms associated with severe infection of corn, but not of *Sorghum* spp., consist of bleaching of the upper leaves and distortion of internodes above the ear. Warm rainy weather conducive to water-gorging of the leaves seems to favor infection in corn. Thus far the disease has not been important on commercial field corn, but only a few very susceptible inbred lines and their progenies.

Introduction.—During the past several years a bacterial disease of corn observed in Indiana appears to be distinct from any of the naturally occurring diseases previously reported for this crop. The disease was present to a mild degree on very susceptible inbred lines in 1949, 1953, and 1958, but in 1957 was especially noticeable.

This paper describes symptoms, cross-inoculations, and laboratory tests designed to identify the pathogen.

Symptoms.—Typical primary symptoms on corn leaves appear as amber- to olive-colored, oil-soaked, translucent lesions that are elongated and generally parallel-sided, and tend to coalesce (Fig. 1-A,B). The disease appears first on the lower leaves, and with

conditions favorable for infection gradually spreads upward; seldom, however, do leaves above the ear become infected. With age, lesions become brown and necrotic. Infected tissue is gorged with bacteria, as attested by the great numbers that issue from fresh sections of diseased leaves mounted in water and observed microscopically.

The most striking aspects of the disease syndrome

Fig. 1.—Symptoms of bacterial stripe of corn. **A)** Typical primary lesions on corn leaf. **B)** Detail of lesions enlarged about 2×. **C)** Sorghum leaf showing typical lesions. **D)** Distortion of internodes as a result of tightly rolled whorl. **E)** Field view showing striation and bleaching of upper leaves. **F)** Acute stage of bleaching of whorl.

are the secondary symptoms attending severe infection of very susceptible inbred lines. One of these is the marked chlorotic striping of the whorl leaves (Fig. 1-E,F). Tissue adjacent to the vascular bundles remains green longest, but eventually the entire leaf blade may become bleached. A second concomitant of severe infection is distortion of upper internodes (Fig. 1-D). The parts of the plant affected with secondary symptoms—the bleached upper leaves and distorted internodes—appear not to be infected. Microscopic observation of sections as well as attempts at isolation from these parts failed to indicate the presence of bacteria.

No stalk rotting has been observed in any plants showing primary or secondary leaf symptoms.

Cross-inoculations.—In 1957, when the disease was especially prevalent, bacterial stripe of *Sorghum* spp., incited by *Pseudomonas andropogonis* (E. F. Sm.) Stapp, was also abundant. The similarity in pattern, but not in color, between lesions on *Sorghum* spp. and those on corn was so striking as to suggest a possible relation between the two diseases (Fig. 1-C). Cultures of *P. andropogonis* isolated from sorghum and sudangrass were compared with the pathogen isolated from corn, by means of all possible cross-inoculations on these 3 hosts.

Young seedlings were inoculated by spraying them with an aqueous suspension of a culture and holding them in a moist chamber at 24–27°C for 24 hours, or by injecting the suspension into the base of the leaf whorl through a hypodermic needle. The latter method was generally more effective, but wounding is not essential and infection is readily established by entrance of the bacteria through stomata. Inoculum was prepared from cultures grown 48 hours on nutrient agar.

All cultures incited typical primary symptoms characteristic of the specific host. On sorghum and sudangrass, elongated, parallel-sided, reddish-purple lesions became fully evident 10 days after inoculation. On corn seedlings, lesions of the same general shape developed, but they appeared oil-soaked, translucent, and amber- to olive-colored. Only in corn seedlings did the secondary symptom, characterized by bleaching of whorl leaves, develop (Fig. 2-A,E). No differences were apparent among the freshly isolated cultures from the 3 hosts so far as the symptoms they incited.

Morphological, cultural, and physiological comparisons.—*Morphology.*—The isolate from corn was a short rod with rounded ends, found singly or in pairs, and measured 1.5–2.5 μ × 0.5–0.8 μ. Cells were motile, and electron micrographs showed each to have a single polar flagellum. The organism was Gram-negative and not acid-fast.

Fig. 2.—Secondary symptoms following artificial inoculation of seedlings with *P. andropogonis*. **A)** Bleached whorl. **B)** Healthy whorl leaf. **C-E)** Striation and near complete bleaching of whorl leaves.

Cultural characters.—On beef-peptone agar at 26±1°C, colonies were 2–3 mm in diameter in 5 days. They were round, smooth, glistening and slightly raised, with centers denser than margins. By reflected light, colonies were white; by transmitted light, amber-colored with fluorescent margins.

On potato-dextrose agar 5-day-old colonies were 2–4 mm in diameter; they were round, smooth, glistening, white by reflected light, and cream-colored by transmitted light.

On gelatin-stab cultures, growth developed at 18°C in 72 hours; no liquefaction was evident in 2 months.

On beef-peptone broth growth was slow, only slight clouding and a fine granular surface growth developed in 24 hours. At 48 hours moderate clouding was evident, and in 5 days tubes showed heavy turbidity.

Physiological characters.—Fermentation

Carbon Source	*Acid*	*Gas*
Arabinose	++	–
Glucose	+	–
Xylose	+ (variable)	–
Mannitol	+ (variable)	–
Lactose	+ (weak)	–
Sucrose	–	–
Glycerol	–	–

The following tests were negative: H_2S production, indol production, gelatin liquefaction, nitrate reduction, and the Voges-Proskauer reaction. Starch hydrolysis was weak and variable, and litmus milk slightly reduced.

On nutrient-agar slants the bacterium showed moderate to good growth in 48 hours over a range of 24–32°C. After 7 days, growth developed slightly at 8°C and abundantly at 36°C. No growth occurred at 40°C, and after 2 weeks at this temperature the organism could not be recovered. Very slight growth was evident at 4°C after 2 weeks. (The writer is indebted to G. H. Peterson, microbiologist, Department of Botany and Plant Pathology, Purdue University, for the electron micrographs and for making some of the physiological determinations.)

The morphological, cultural, and physiological characteristics of the bacterium isolated from corn corresponded closely with those of cultures of *P. andropogonis* isolated from sorghum and sudangrass.

Field inoculations.—During the several years that the disease has been observed the corn inbred lines Oh28 and P8 seemed somewhat more susceptible than others. To obtain further information on relative susceptibility, 50 inbred lines were inoculated in the field by spraying a suspension of the bacterium into whorls of 7-week-old plants. Two weeks later they were scored for their relative susceptibility. Those showing extreme susceptibility were Oh28, L304A, Oh40B, H14, and P8; those most resistant were R39, B37, Ill. 90, and K148. In the most susceptible inbred lines, as in natural infection, the typical secondary symptoms of bleaching of upper leaves and distortion of internodes above the ear followed severe infection of lower leaves.

Stalk inoculations were made on some plants by injecting either a suspension of a pure culture or a macerate of naturally infected leaves. None of these inoculations resulted in establishment of the disease in stalk tissue.

Ears were collected from severely diseased plants, infected either through natural or by artificial means to determine whether the disease could be transmitted through the seed. The seed was dried and planted in a greenhouse maintained at a minimum air temperature of 24–27°C. During 2 months, in which 85 plants grown from such seed were observed, no infection could be found.

Discussion.—In 1905 Smith and Hedges (4) first described a bacterial stripe disease of sorghum. Later, Smith (3) briefly characterized the causal organism and named it *Bacterium andropogoni*. In 1929, Elliott and Smith (1) published a detailed account of the disease and the causal organism. They were able to inoculate corn (variety Boone County White) artificially, but no mention is made of natural occurrence of the disease on the crop. Bleaching of upper leaves following severe infection was not observed.

Of the bacterial diseases of corn, this one bears some resemblance only to bacterial leaf blight and stalk rot incited by *Pseudomonas alboprecipitans* Rosen (2). The latter disease is characterized by shredding of the infected leaves and rotting of the stalk above the ear. Multiple ears and barrenness frequently accompany severe infection. In these respects the disease differs from bacterial stripe. Bleaching of the leaves above the ear and distortion of upper internodes have not been described as symptoms of bacterial leaf blight and stalk rot.

P. andropogonis differs from *P. alboprecipitans* in cultural behavior, but primarily in the fact that the latter organism reduces nitrate, liquefies gelatin, and makes earlier growth at 36° and none at 8 or 4°C. *P. alboprecipitans* appears to be much more virulent when artificially inoculated into corn seedlings than does *P. andropogonis* and produces on such plants symptoms distinct from those incited by the latter. These differences, both in the characteristics of the pathogens and symptoms incited on the host, were verified by comparing cultures of *P. andropogonis* isolated from corn, sorghum, and sudangrass leaves with *P. alboprecipitans* isolated from a diseased corn leaf kindly furnished by Alice L. Robert.

The occurrence of bacterial stripe of corn has usually followed periods of warm rainy weather when leaves tend to become water-gorged.

The disease has not been of economic importance on any of the common hybrids under field conditions. In only a few very susceptible inbred lines and their progenies has the disease been severe enough to reduce seed production.—Department of Botany and Plant Pathology, Purdue University, Lafayette, Indiana.

LITERATURE CITED

1. Elliott, Charlotte, and E. F. Smith. 1929. A bacterial stripe disease of sorghum. J. Agr. Research 38:1-22.

2. Johnson, A. G., Alice L. Robert, and Lillian Cash. 1949. Bacterial leaf blight and stalk rot of corn. J. Agr. Research 78:719-732.
3. Smith, E. F. 1905-11. Bacteria in relation to plant diseases. V. 1-2, Washington, D. C. (Carnegie Inst. Wash. Publ. 27).
4. Smith, E. F., and F. Hedges. 1905. Burrill's bacterial disease of broom corn. (Abstr.) Science (n.s.) 21:502-503.

THE ROLE OF INFESTED STRAW IN THE EPIPHYTOLOGY OF SEPTORIA LEAF BLOTCH OF BARLEY

Richard W. Lutey and Karl D. Fezer

Research Fellow and Asst. Prof., respectively, Department of Plant Pathology and Botany, University of Minnesota.
Accepted for publication July 5, 1960.
Paper No. 4357, Scientific Journal Series, Minnesota Agricultural Experiment Station.
Based on part of an M.S. thesis by the senior author, University of Minnesota. Research supported in part by the Malting Barley Improvement Association, Milwaukee, Wisconsin.

SUMMARY

Although present since 1914, *Septoria passerinii* caused a severe epiphytotic of Septoria leaf blotch on barley in the Red River Valley of Minnesota for the first time in 1955 and has been prevalent since then. Possible reasons for this increase in Septoria leaf blotch are suggested. It is proposed that infested straw is the primary form in which the pathogen survives one or more winters, and in which it is spread from field to field. Field observations indicated that, once established, the fungus produces abundant pycnidia on senescing plants, even in years when the disease develops too late to cause much damage. Laboratory experiments proved that the number of pycnidia in lesions on barley straw can increase. The fungus can survive in straw, either in or on the soil, for at least 2 winters. Cultural practices in the Red River Valley, the level terrain, and high winds all favor wind transport of infested straw among fields. These facts help to account for the supply and distribution of inoculum required to obtain the prevalence of Septoria leaf blotch that has been observed in the past few years. It was shown that conidia are available on infected plants after rain and that insects can pick up conidia from moist straw. Both insects and splashing raindrops may be important in bringing the pathogen from infested straw to infection courts. No evidence was obtained that conidia are wind-borne. Pycnidia on infested straw can liberate conidia even after repeated wetting over a period of several months. Pathogenic differences among isolates of *S. passerinii* were demonstrated.

Septoria leaf blotch of barley (*Hordeum vulgare* L.), caused by *Septoria passerinii* Sacc., was reported from Minnesota and neighboring states in 1914 and 1915 (4, 6) but was absent or scarce until the mid-1940's. No severe epiphytotic was reported until 1955 (2). Since then the disease has been less severe but has nevertheless been omnipresent annually on the barley crop in the Red River Valley. A study was made of the mechanisms of build-up, over-wintering, and dissemination of *S. passerinii*.

Description of the disease.—In the field, symptoms on susceptible varieties appear to be of 3 kinds, depending on the age of the barley. On young plants, lesions occur mainly on leaf blades and are grayish-green, turning to a light tan. These lesions are of indefinite size and shape, not being delimited by veins. They may or may not contain pycnidia. About the time plants are heading, mature lesions usually contain pycnidia and are light gray to white, delimited by veins, and therefore characteristically rectangular. In green tissue, these lesions apparently expand no further. On senescing leaf blades and sheaths, however, the fungus apparently spreads rapidly and produces large blotches densely populated with pycnidia. Pycnidia on leaf blades are 70–140 μ in diameter, and those on sheaths are 45–70 μ. These are commonly associated with stomates and occur in rows parallel to the veins (Fig. 1). A gray discoloration of the tissue in these pycnidial blotches is especially conspicuous on bright straw (Fig. 2). Since 1955 it has been common to find all plants in ripe barley fields in the Red River Valley with over 20–30% of their leaf-sheath area covered with pycnidial blotches.

Build-up of inoculum on straw.—A procedure was devised to detect further development of the fungus already established in dead host tissue. Infested barley straw was first washed in running water for 8–10 hours. Then all microscopically visible pycnidia in selected lesions containing 100 or more pycnidia were mapped, using a Carl Zeiss drawing apparatus. The pieces of straw containing the mapped lesions were then surface-disinfested in 1% NaOCl for 2 minutes and placed into sterile Petri plate moist chambers, which were incubated at 5–7, 15, 25, and 30°C. Lesions were re-mapped after 2, 4, 6, and 8 weeks of incubation to detect the appearance of new pycnidia, either within or outside the boundaries of the original lesions. The experiment was repeated with the lesions being re-mapped after 2, 6, and 10 weeks. Straw tissue was surface-disinfested in 1% NaOCl after each remapping. A third experiment included a separate lesion for each date of sampling—4, 8, and 12 weeks after the beginning of incubation—at each of the 4 temperatures. This permitted newly formed pycnidia to be checked for the presence of conidia on each sampling date, and for such pycnidia to be cultured in order to determine their pathogenicity. Newly formed pycnidia were also checked for the presence of conidia at the conclusion of each of the first 2 experiments.

Pycnidia did not develop beyond the limits of the original pycnidial blotches. New pycnidia did appear within these blotches, however, when the tissue was incubated at 15–30°C. Results of the first 2 experiments are summarized in Table 1. Similar data were

obtained from the third experiment; in this, a 4% increase in the number of pycnidia was observed after 12 weeks at 5–7°C. Normal conidia were present in newly developed pycnidia in all samples examined, and cultures derived from these pycnidia were pathogenic.

Over-wintering.—The viability of *S. passerinii* in straw exposed to various conditions was determined by culturing pycnidia. Pieces of infested straw or leaf material were washed in running tap water for 12–18 hours and then immersed in 1% NaOCl for 2 minutes. Individual pycnidia were then picked off with a sterile needle under a dissecting microscope and transferred to potato-dextrose agar slants. Pycnidia that produced pink, yeastlike colonies after 2 weeks at room temperature were assumed to contain conidia and were classed as viable.

In April-June, 1958, barley straw or stubble from the 1957 crop, buried over 6 in. deep, was collected in 3 fields in the Red River Valley. Severely weathered barley straw was collected from roadsides and fields planted to other crops. All these collections yielded viable cultures of *S. passerinii*.

In an attempt to determine the range of conditions under which *S. passerinii* can over-winter, equal amounts of infested straw from the 1957 barley crop were enclosed in chicken-wire envelopes and a) buried in the field at a depth of 12 in., b) buried at a depth of 6 in., c) placed on the ground in contact with the soil, and d) suspended in air. These treatments were compared with e) infested straw stored at room temperature and with f) pycnidium-containing Septoria lesions in green leaf tissue stored in a freezer at 4°F. All treatments were initiated on November 1, 1957, and the samples of straw were removed to room temperature on May 1, June 1, and October 1, 1958. Within a few days of each sampling date (a month after the last sampling date), 70–86 pycnidia were cultured from samples of each treatment.

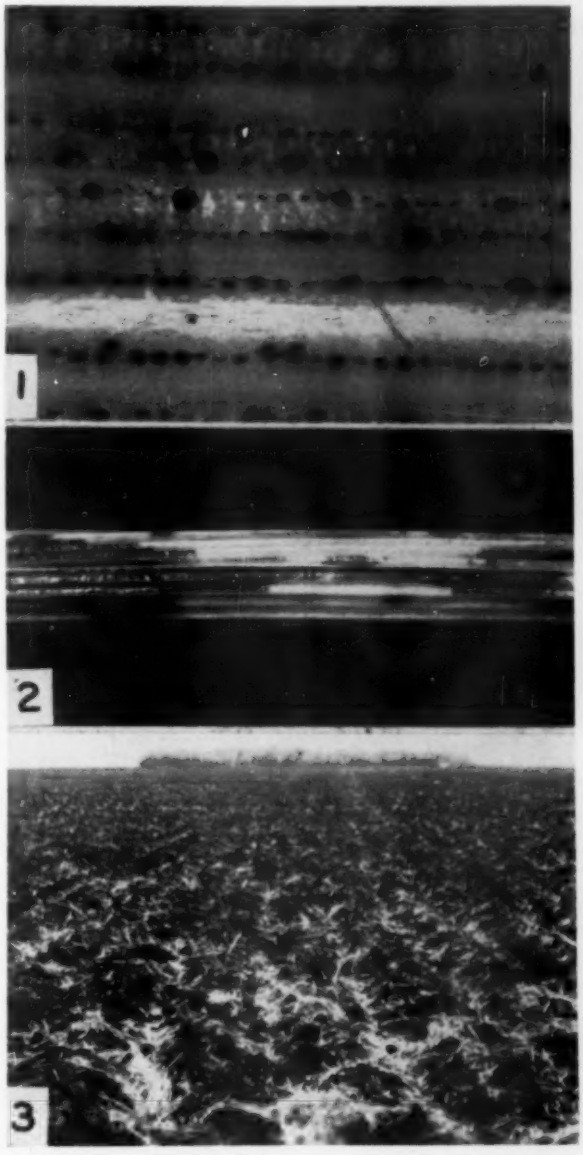
S. passerinii remained viable through the last sampling date in all treatments. There were no consistent differences in the number of cultures of the fungus obtained from straw subjected to the 4 outdoor treatments. In these treatments, the average percentage of pycnidia giving rise to cultures of the fungus on the first, second, and third sampling dates was respectively 31, 16, and 14. Colonies of other fungi developed in some slants and may have obscured additional colonies of *S. passerinii*. Sixty-nine per cent of the pycnidia from straw stored at room temperature, and 78% of the pycnidia from lesions on green tissue stored in a freezer, produced cultures of the fungus. In neither case was there a decline in viability during the test period.

For each treatment in this experiment, cultures of *S. passerinii* obtained from the straw of that treatment were bulked, and the mixture tested for pathogenicity to Kindred and Minn. II-48-45 barley in the green-

Table 1.—Percentage increase over the original number of pycnidia in lesions of Septoria leaf blotch, incubated at 4 temperatures for 5 periods.[a]

Incubation temperatures (°C)	Number of weeks incubated				
	2	4	6	8	10
5–7	0	0	0	0	0
15	0	0	7	8	60
25	5	6	23	38	>200
30	7	7	7	40	53

[a] This table combines the data of 2 experiments, with lesions remapped after 2, 4, 6, and 8 weeks in one, and after 2, 6, and 10 weeks in the other. Thus, each datum is based on 1 or 2 lesions, with over 100 pycnidia in each.



Figs. 1–3.—**1)** Pycnidia in rows parallel to the veins in part of a lesion of Septoria leaf blotch on leaf sheath tissue. **2)** Lesions of Septoria leaf blotch on barley straw. **3)** Barley straw in a field in the Red River Valley. Photograph taken immediately after spring tillage.

house. All these inocula were pathogenic to both varieties.

In November, 1958, at St. Paul, wire envelopes containing straw from the 1958 barley crop were buried at a depth of 6 in. or placed on the ground in contact with field soil. Straw in these envelopes was sampled on March 14, 1960. Some of the pycnidia from straw of each treatment contained conidia that germinated within 48 hours when incubated in water drops at room temperature. This proves that *S. passerinii* can survive for 2 winters in Minnesota.

Wind dissemination.—Barley straw and stubble infested with Septoria are abundant on the soil surface after harvest of the barley crop in the Red River Valley (Fig. 3). The terrain in the Valley is flat, and winds often reach high velocity. The average wind velocity for April, 1958, at Fargo, North Dakota, was 17 mph, with gusts up to 54 mph. Winds of 15 mph or more were observed blowing straw across fields, roads, and drainage ditches. In June, 1958, a 3×5-ft wire net, placed 50 yards from the nearest field planted to barley in 1957, trapped a large handful of infested straw in a week. Cultures of *S. passerinii* were obtained from this straw.

To investigate the possibility that conidia of *S. passerinii* are disseminated by wind, weather-vane spore traps were set out in 12 barley fields in the Red River Valley in 1958. Vaseline-coated slides were held at a height of about 40 in., facing into the wind and downward at an angle of 13° from the vertical. The slides were replaced at 2-week intervals from April to mid-July and examined for conidia of Septoria. None were found.

Dissemination of conidia by insects.—Straw heavily infested with *S. passerinii* was soaked in water and incubated for several days in a mist chamber. Unidentified flies, and larvae and adults of a lady bird beetle, were trapped and sealed in a container with the pre-soaked straw. One day later, conidia of Septoria were observed on leg hairs of the insects. *S. passerinii* was not obtained, however, from aphids, leafhoppers, and lady bird beetle larvae collected in the field in dry weather and after a rain, although attempts were made to isolate the fungus by plating both entire insects and the water used to rinse them.

To ascertain whether animals could serve as vectors, Vaseline-coated slides were attached to the clothing of individuals who walked through a barley field with a high prevalence of plants infected with Septoria before and after a rain in mid-July, 1958; no conidia of Septoria were found on slides before the rain, but conidia were abundant on slides after the rain.

Dissemination of conidia by splashng water.—Drops of water (0.07 ml) were allowed to fall from a height of 23 ft onto pre-moistened infested straw. Droplets containing conidia of Septoria were splashed a horizontal distance of 3 ft from the point of impact.

Infested straw as a source of inoculum after repeated wetting and drying.—Infested straw in chicken-wire envelopes was suspended over 2 flats containing seedlings of Kindred barley. The flats were placed in a mist chamber for 4 days and then returned to the greenhouse. Septoria leaf blotch developed abundantly. The procedure was repeated 4 times during a 3-month period, using new seedlings but the same envelopes of straw. Between wettings, the straw was stored dry at room conditions. About the same amount of Septoria leaf blotch developed each time, indicating that infested straw may serve as inoculum even after repeated wetting.

Differences in pathogenicity of isolates of Septoria.—Nine culture types of *S. passerinii* were selected from more than 500 single-pycnidium isolates. Ten-day-old cultures of the 9 types ranged from pink yeastlike colonies to carbonaceous aggregates. Two of the types had white aerial mycelium. Differences in cultural appearance diminished as the cultures aged, and it is possible that these differences, in part, reflected differences in rate of colony maturation. However, the 9 distinct culture types were recovered by making fresh transfers and were maintained through repeated subculturing.

The pathogenicity of 4 of these culture types was tested on the following 4 barley varieties: Kindred and Minn. II-48-45, which are susceptible to Septoria leaf blotch; N.D. B112, which is somewhat resistant; and Minn. II-51-43, which is resistant. A suspension of conidia in a 0.5% gelatin solution, at a concentration of 250,000 conidia per ml, was prepared for each isolate tested. These suspensions were divided into three 50-ml portions, to each of which was added 2 drops of Polyethylene Glycol 400. Each aliquot was sprayed onto 4 varieties, 3 pots per variety, 15–20 plants in the 4-leaf stage per pot. The plants were incubated for 5 days in a mist chamber and then kept at 70°F in a greenhouse. Sixteen days after inoculation, seedlings were rated on a disease severity scale of 0–5, with 5 most severe. The severity ratings were based on the amount of necrotic area. Pycnidia developed within some distinct lesions on all seedlings with disease severity ratings of 1 or more. More pycnidia developed on seedlings with severe infection than on seedlings with slight infection.

The data in Table 2 indicate considerable differences in the amount of infection occurring on a single variety inoculated with different isolates of the organism. It appears from Table 2 that at least 3 of the 4 isolates tested were pathogenically distinct.

Discussion.—In the 10 years preceding the first severe epiphytotic, Kindred barley rapidly became the leading variety grown. In 1952–56, over 90% of the barley acreage in Minnesota was planted to Kindred; 97% in 1956 (1). It is likely that culture of Kindred partly accounts for the epiphytotic of this disease. Before 1955, naturally occurring Septoria leaf blotch was conspicuous on Kindred in varietal trials in barley-growing areas. Kindred was probably more susceptible than other varieties to prevalent races of *S. passerinii*. In addition, the demonstration of pathogenic races in this fungus adds the possibility that previously rare biotypes increased on Kindred. The barley varieties that Kindred replaced are also susceptible to biotypes

Table 2.—Average severity of Septoria leaf blotch on 4 varieties of barley inoculated with 4 single-pycnidium isolates.

Variety	Previous field reaction[a]	Isolate no. 1	2	3	4
Minn. II-51-43	R	1.0[b]	1.0	4.0	0.7
No. Dak. B112	MR	3.3	3.3	5.0	0.7
Kindred	S	2.3	2.0	4.0	0.3
Minn. II-48-45	S	2.0	2.7	5.0	0.0

[a] R = resistant, MR = moderately resistant, S = susceptible.

[b] Septoria leaf blotch severity ratings based on a scale of 0–5, with 5 most severe. The severity ratings were based on the amount of necrotic area, including both distinct lesions and fired tissue. Each datum in this table is an average of the ratings given 3 pots, each containing 15–20 seedlings. In no case did the 3 ratings differ from one another by more than one severity class.

of the fungus that are prevalent now. With combine harvesting, more straw and crop residues are left in the field; this also may have increased inoculum of *S. passerinii*.

Both the nature of the disease and cultural practices in the Red River Valley of Minnesota can account for the continued high prevalence of the disease once the epiphytotic of 1955 had provided large quantities of inoculum. Pycnidia are produced abundantly on the barley plant as the grain ripens, even though the fungus grows slowly on growing plants. Thus, the fungus perpetuates itself, even in years when the build-up of Septoria leaf blotch is too delayed to cause much damage to the barley crop. This phenomenon has been observed in barley fields in the Red River Valley each year since 1955. In addition, it was shown that the number of pycnidia may increase even further on dead straw.

It is proposed that infested straw is the primary form in which the pathogen over-winters and in which it is spread from field to field. It was shown that the fungus can survive at least 2 winters in barley straw, either buried in the soil or exposed to the atmosphere on the soil surface. In the Red River Valley, barley straw remains on the field after combining. Either fall or spring tillage is shallow, so that not all the straw is buried. With subsequent tillage, much of the buried straw is brought to the soil surface. Therefore, wind may carry infested straw to adjacent fields, or even further, both before and after tillage. Even moderate winds were observed carrying straw 50 or more yards, especially from fields where crop debris had been loosened by recent tillage. Strong winds may carry straw much further, but short-range field-to-field dispersal can also account for the widespread occurrence of the fungus in the Red River Valley. Over 15% of the total area of the Red River Valley in Minnesota is planted to barley every year. This means that barley frequently follows itself in succeeding or in alternate years, and it is likely that a barley field will be near a field that was in barley the previous year. These facts help to account for the supply and distribution of inoculum that is required to obtain the prevalence of Septoria leaf blotch observed in the past few years.

Pycnidia have been reported on awns of barley (3). These, and small pieces of straw in barley seed lots, may bring the pathogen to new areas. However, infection of floral parts is probably unimportant in the epiphytology of the disease once it is established in an area.

Although insects were not shown to transmit conidia of *S. passerinii* in the field, it was shown that conidia are available after moist periods and that insects can pick conidia up from moist straw. While this mechanism may function somewhat in field-to-field spread of the disease, it is more likely that it is important in bringing the pathogen from infested straw to infection courts within localized areas. Rain simultaneously washes insects off the plants and initiates pycnidial oozing; insects are thus likely to encounter conidia. Further evidence obtained indicates that splashing raindrops also carry conidia to infection courts. No evidence was obtained that conidia may be wind-borne.

The relative importance of secondary infections in the development of Septoria epiphytotics is not known. Since long moist periods appear to be necessary for infection (3, 5), conditions conducive to infection may not occur often during the growing season. When favorable moist periods do recur, infested straw can again serve as a source of inoculum. Together, these observations suggest that primary inoculum from infested straw may account for a large proportion of infections, even in epiphytotic years.

The existence of pathogenic differences among isolates of *S. passerinii* was also demonstrated. This is particularly significant because the use of varieties resistant to the disease appears to be the most effective means of control. Barley varieties now being bred for resistance to Septoria may encounter races of the fungus to which they are susceptible.— Department of Plant Pathology and Botany, Institute of Agriculture, University of Minnesota, St. Paul.

LITERATURE CITED

1. Anonymous. 1956. Barley Variety Survey. *In* Progress report, annual meeting of Malting Barley Improvement Association, Nov. 29, 1956, p. 23-25.

2. Christensen, J. J., and B. L. Renfro. 1956. Septoria becomes epidemic in the Red River Valley. Malting Barley Improvement Association, 2 p. (Mimeo.).

3. Green, G. J. 1957. Pathological histology and varietal reaction on Septoria leaf blotch of barley. Phytopathology 47:73-79.

4. Johnson, A. G. 1916. Septoria on barley. Phytopathology 6:117.

5. Koble, A. F., G. A. Peterson, and R. G. Timian. 1959. A method of evaluating the reaction of barley seedlings to infection with Septoria passerinii Sacc. Plant Disease Reptr. 43:14-17.

6. Weber, G. F. 1923. Septoria diseases of rye, barley, and certain grasses. Phytopathology 13:1-23.

HOST-PARASITE INTERACTIONS OF EIGHT VARIETIES OF OATS INFECTED WITH RACE 202 OF PUCCINIA CORONATA VAR. AVENAE

P. G. Rothman

Research Agronomist, Crops Research Division, ARS, U.S.D.A., Stoneville, Mississippi.

Accepted for publication July 21, 1960.

Contribution from the Agronomy Department, Illinois Agricultural Experiment Station, Urbana. Published with the approval of the Director. Portion of a Ph.D. thesis. The author expresses appreciation to Dr. O. T. Bonnett and Dr. W. M. Bever, under whose guidance this study was made. Acknowledgement is also made to the Quaker Oats Company for funds in support of this research.

SUMMARY

Macroscopic observations of perceptible changes observed on the leaves of 8 oat varieties inoculated with *Puccinia coronata* var. *avenae* made possible the classification of the varieties into 4 distinct groups. Microscopic differences characterizing the 4 groups were: the physical appearance of the substomatal vesicle and the growth of the infection tube, the number of nuclei present in the infection hyphae, the staining characteristic of the mycelium, haustoria formation, the extent of penetration of the hypha within the leaf, cellular disturbances of the host cells, and the reproductivity of the parasite. The normal pattern of rust development in a susceptible host occurred in the first group. In the second group not all substomatal vesicles sent out infection hyphae, and the rate of growth of the parasite lagged 24 hours behind the developmental pattern in the first group. Also, uredia were surrounded by a definite chlorotic area. Substomatal vesicles appeared granular in the third and fourth groups, with only the actively growing tips of the mycelium filled with dense protoplasm. Antagonistic reactions between host and parasite occurred 72 hours after inoculation within the third group. Rapid necrosis of the entire inoculated leaf arrested the further spread of the parasite. Cellular disorganization of the host plant followed 18 hours after inoculation of varieties of the fourth group. Hypha penetration and haustoria formation were checked by the breakdown of host tissue. Only the tissue invaded by mycelium was destroyed.

The response of any single oat variety to the various physiological races of crown rust, *Puccinia coronata* Cda., can vary from complete susceptibility to high resistance. The present investigation is a study of the developmental pattern of the rust parasite and of the histological effects within the leaf tissue that are related to this pattern.

The earliest theories advanced a mechanical phenomenon to explain the various degrees of resistance to rust that are exhibited among the varieties of cereals and grasses. Cobb (3) was first to advance this mechanical theory. Morphological characters such as size of stomata, thickness of leaf cuticle, waxy coverings, leaf pubescence, or angle of leaves on the stem were thought to be responsible for resistance in certain varieties. Hitchcock and Carleton (6), working with wheat varieties with stiff upright leaves versus limp or flaccid leaves, supported Cobb's theory.

In 1902, Ward (13), from a large number of inoculation experiments with *Puccinia dispersa* on *Bromus* spp. and detailed histological investigations of the host, found that such correlations were invalid. Resistance depended entirely on the physiological interaction of the protoplasm of the fungus and the host.

Later workers demonstrated that rust urediospores germinated on both susceptible and resistant host varieties and gained entrance primarily through the stomata. In resistant varieties, fungal development was checked by a deterioration and collapse of the host cells surrounding the invading mycelium. In susceptible varieties the host cells remained turgid and healthy, giving nourishment to the fungus for an extended period. Agreement is lacking among the various workers as to the cause of the noncompatibility between the fungus and host in the resistant varieties.

Differences in adaptability, according to Ward (14) may be the result of starvation of the mycelium due to unsuitable food supplied by the tissues of the host plant, or to the vigorous onslaught of the parasite, preventing the mycelium from advancing through the destroyed tissues. Gibson's (5) work suggests that the death of the hyphae is due to some poisonous substance emitted by the host cells. Marryat (8) presumed the reaction to be a function of certain toxins and antitoxins that are mutually destructive, the host and the parasite both being responsible for their production. Bolley (2) concluded also that chemical agencies, perhaps toxins, resulting from the direct attack of the fungus upon the host were responsible. Whatever the intimate physiological relations between host and fungus, Stakman (11) attributed the death of the host cells directly to the presence of the hyphae. In explanation he advanced his "hypersensitive" theory (12), that immunity is due to some physiological incompatibility resulting in abnormally rapid death of the host cells when attacked by the rust hyphae. Newton's (9) observation closely followed those of previous workers, but she suggested that infection is dependent upon a delicate balance between the host and fungus. The susceptible host readily adjusts itself to the presence of the parasite whereas the resistant host remains intolerant of the fungus.

Wellensiek (15), in his work with corn, thought that the differences between susceptible and resistant plants were quantitative and could be explained by the assumption that the amount of a nutritive substance present in a particular corn variety determined the degree of susceptibility.

Materials and methods.—Of the 8 oat varieties selected for this study, 4 exhibited a high degree of resistance to race 202 of crown rust with varying patterns of chlorosis and/or necrosis, 3 were highly susceptible, and 1 was intermediate in response. The four resistant types were: Landhafer (C.I. 3522), Santa Fe (C.I. 4518), Clintland (C.I. 6701), and

Clintafe (C.I. 5869). The three susceptible types were: Marion (C.I. 3247), Clinton 25, and Columbia (C.I. 2820). The intermediate variety was Tama (C.I. 3502).

Each of the eight oat varieties was grown in the greenhouse in 4-in. pots. Inoculation was effected when the first leaf blade had about 2 in. of flat surface. The inoculated portions of leaves were removed at 12, 24, and 36 hours and at additional 24-hour intervals up to 240 hours after inoculation, and killed and fixed in formalin-aceto-alcohol solution. By this time, uredopustules had generally made their appearance in the susceptible varieties and necrosis had developed in the resistant varieties, rendering them undesirable for further histological study.

The development of the fungus was observed from the period of spore germination up to the time it had successfully reproduced itself on its particular host, or had died. Early stages of spore germination, germ tube growth, and appressorial development were examined in living as well as in fixed material. Whole-leaf sections of inoculated oat leaves were stained according to Bell (1). Fixed material was embedded in paraffin with the tertiary-butyl alcohol method of Johansen (7), and stained with safranin and fast green by an improved method worked out by Cross (4).

Experimental results.—Classification of group types.—The rust reactions of the 8 oat varieties were classified into 4 distinct groups, based on differences in the appearance of the inoculated leaves, microscopic observations of the histology of the leaves of the host at the point of infection, and the growth patterns of the pathogen. The groups, and the varieties within each group are: I—highly susceptible (large uredia, without necrosis or chlorosis): Columbia (Fig. 1-A), Clinton 25 (Fig. 1-B), and Marion (Fig. 1-C). II—intermediate (variable-sized uredia, some with necrosis and/or chlorosis): Tama (Fig. 1-D). III—resistant (necrotic areas, with minute uredia): Clintafe (Fig. 1-E) and Clintland (Fig. 1-F). IV—highly resistant (necrotic areas, without minute uredia): Santa Fe (Fig. 1-G) and Landhafer (Fig. 1-H).

Macroscopic observations.—The various developmental stages observed in inoculated leaves of the host were designated as flecking, chlorosis, necrosis, raised epidermis, ruptured epidermis, and pustule formation. Examination of sections taken within the flecking area of inoculated leaves of all 8 varieties showed that the mottle appearance of the epidermis was due to 2 unrelated and independent causes. First, the loss of green coloring resulted from the destruction of the chloroplasts within the attacked cells, thus leaving a colorless area. Second, flecking was the result of the massing of mycelium within the intercellular spaces below the epidermis. This resulted in separation of the epidermal cells, which are without chloroplasts, from the chlorophyll-containing hypodermal cells by the hyaline massing weft of hyphae. Chlorosis, or extensive yellowing of tissue, which develops in the inoculated leaf, is the result of the

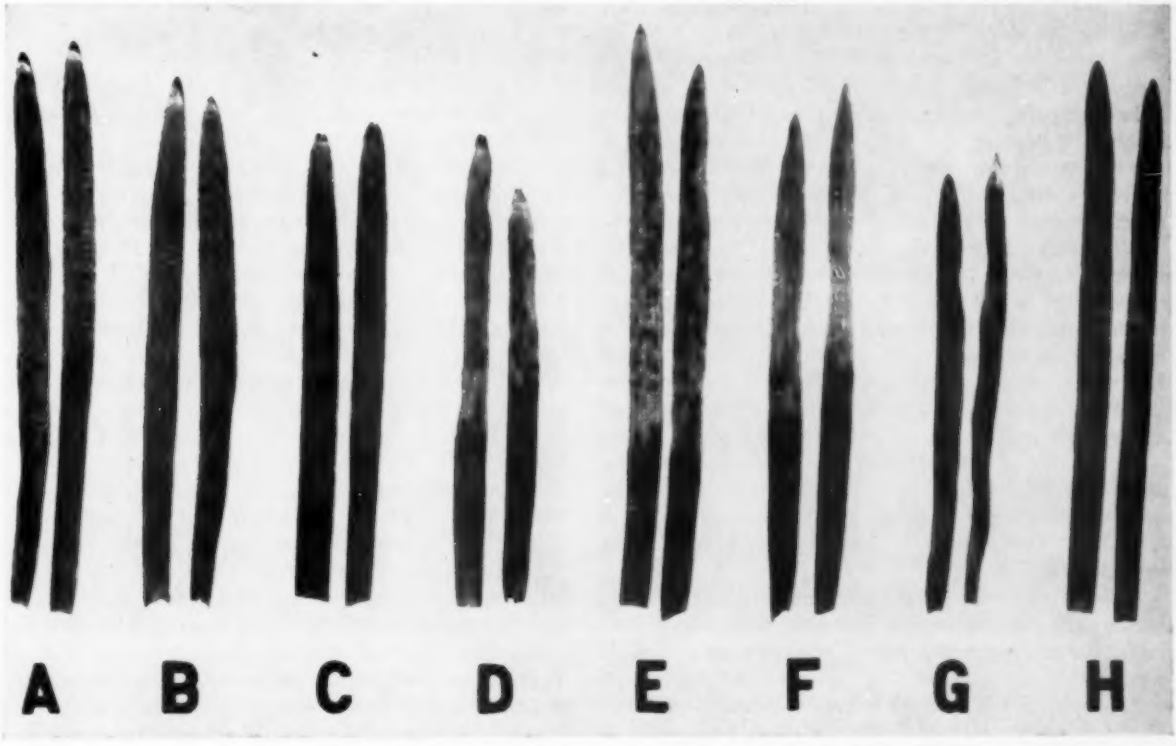


Fig. 1.—Crown rust reaction of eight oat varieties 240 hours after inoculation: **A)** Columbia, **B)** Clinton 25, **C)** Marion, **D)** Tama, **E)** Clintafe, **F)** Clintland, **G)** Santa Fe, **H)** Landhafer.

partial break-down of the chloroplasts within the infected area. Necrosis, evidenced by brown or black plant tissue, is the culminating point in the sequence of cellular disorganization brought about by the host-pathogen interaction. The raised appearance of the epidermis is first observed when the fungus begins to aggregate in wefts, within the large air spaces of the mesophyll under the epidermis prior to the formation of the uredium. Pressure of the developing urediospores against the epidermal cells causes the epidermis to rupture. The spores in the sorus adhere to each other with each successive division, and are soon elevated above the ruptured epidermis, forming a yellow-orange pustule.

Flecking of the leaves of the highly susceptible group I appeared in 5–7 days following inoculation. Chlorosis and necrosis were absent. The raising of the epidermis became apparent after the 7th day. The swellings continued to enlarge at the site of flecking, and by the 8th to 9th day after inoculation the epidermis ruptured and the urediospores emerged.

In the intermediate Group II, flecking of the epidermis became apparent in 5–7 days. Chlorotic areas bordering the incipient swellings became manifest on the inoculated leaves about the 8th day. Urediospores emerged through the ruptured epidermis by the 9th day. Necrosis of leaf tissue was generally absent.

Eight days after the seedling leaves of the varieties in Group III (resistant) were inoculated, flecking appeared, which was soon followed by yellow areas that grew rapidly and coalesced. Occasional minute urediosori were found breaking through the epidermis after the 9th day. By the 10th day following inoculation, extensive areas encompassing nearly the entire inoculated leaf surface were discolored.

In Group IV (highly resistant) flecking was apparent by the 8th day after inoculation. By the 10th day the extent of infection, as evidenced by chlorotic and necrotic tissue, was limited to small bands within the nearly normal green leaf. Pustules were absent.

Microscopic observations.—A study of serial sections taken through the point of infection showed that certain phases in the life cycle of the rust parasite are common to all the varieties. These similarities include: a) initiation of urediospore germination within twelve hours of inoculation; b) development of a germ tube, 3.5–4.0 μ in diameter (Fig. 2-A-1); c) formation of an appressorium at the tip of the germ tube over a stoma (Fig. 2-B-1); d) penetration of the stomatal slit by an appressorial peg (Fig. 2-B-2); e) swelling of the appressorial peg within the substomatal cavity (Fig. 2-B-3); f) development of the substomatal vesicle and infection hyphae (Fig. 2-C).

Differences in the development and behavior pattern of the parasite, and in the histology of the host varieties, became apparent after the substomatal vesicle formed.

1) *Group I.*—Within 12 hours of inoculation, infection hyphae had issued from the constricted ends of the substomatal vesicle. Well distinguished nuclei were apparent within the reticulum of the hyphal threads and vesicle. There was an almost simultaneous development of both threads arising from a single vesicle, and dichotomous branching of the infection hyphae had begun within the substomatal cavity 24 hours after inoculation. Rapid and profuse branching of the binucleate hyphae, within the intercellular spaces of the resophyll, was initiated by the 48th hour. The protoplasmic contents of the branching hyphae threads remained well distributed. The mycelium grew intercellularly, applying itself closely to the host cells or traversing the open spaces of the mesophyll. Numerous haustoria were present, with two or more projecting into the same cell. The nuclei of these unimpaired host cells moved over to the haustoria that had penetrated them, and lay in close contact. No deleterious effect on the nuclei was seen. The host cells for the most part were turgid and contained a normal complement of chloroplasts. Even at the period of the greatest activity of the fungus, 216 hours after inoculation, the nuclei and chloroplasts of the host cells showed no measurable reduction in size or shape. Hyphae arising from a single infection site expanded to cover extensive areas within the intercellular spaces of the leaf (Fig. 2-D), and intermingling of the hyphae from adjacent infection points followed. After 120 hours the marginal hyphal threads turned and grew toward either surface of the leaf, filling in the larger cavities beneath the epidermis (Fig. 2-E). Protoplasm aggregated in the tips of the surfacing hyphae, whereas the mycelium in the center of the infection showed signs of becoming drained. At 160 hours after inoculation, spore mother cells formed within the developing sorus, and the epidermal cells became distended (Fig. 2-F).

2) *Group II.*—In Group II not all substomatal vesicles that formed during the first 12 hours following inoculation gave rise to infection hyphae. Many vesicles showed a clumping of their protoplasmic contents. Hyphae nuclei were distinguishable, but the development of the mycelia was slow even in the successfully established infections. Branching of the infection hyphae did not become apparent until 72 hours after inoculation. Cellular changes in which the chloroplasts took on a kidney shape and decreased sharply in size occurred in leaf areas away from the center of infection. Penetrations of the host cells by haustoria mother cells were more numerous and successful within the area of the mesophyll densely invaded by mycelium. By the 144th hour, hyphae from bordering infection sites intermingled, and in the next 24-hour interval marginal hyphae had turned and started growing toward the epidermis. Abstricted urediospores aggregated just beneath the epidermis 216 hours after inoculation. Pressure exerted by the production of urediospores caused portions of the epidermis to distend and to rupture. Cells of the host tissue for some distance around the infection site showed impoverishment and destruction of cellular contents. Host cells within the center of the infection area, however, were turgid and showed no apparent reduction in size of the nuclei or chloroplasts.

3) *Group III.*—The physical appearance of both the substomatal vesicles and infection hyphae of group III was different from that of those of Groups I and II. Clear-staining nuclei and well distinguishable reticulated cytoplasm were absent. Vesicles were granular and lacked discernible physical features. Not all vesicles sent out infection hyphae; many withered and died. Only the growing tips of the mycelium retained dense concentrations of protoplasm. Older hyphal threads did not appear drained, but rather appeared to be plasmolyzed. Clumping and shrinking of the nuclear contents of the host cells was evident 72 hours after inoculation. Few haustoria appeared in the leaves sampled after 96–120 hours, and cells in the vicinity of the branching hyphae showed a progressive disorganization in structure. Many isolated hyphal threads persisted in the leaf sections, but they did not extend far from the point of infection. The haustoria that were formed remained small, misshapened, and drained without fully expanding. Hyphae continued to grow beyond the collapsed host cells after 168 hours following inoculation. Host cells contiguous to the scattered hyphae were destroyed or reduced in size. A general destruction of the mesophyll accompanied the collapse of the mycelium within the sections 192 hours after inoculation. Ordinarily the fungus died without

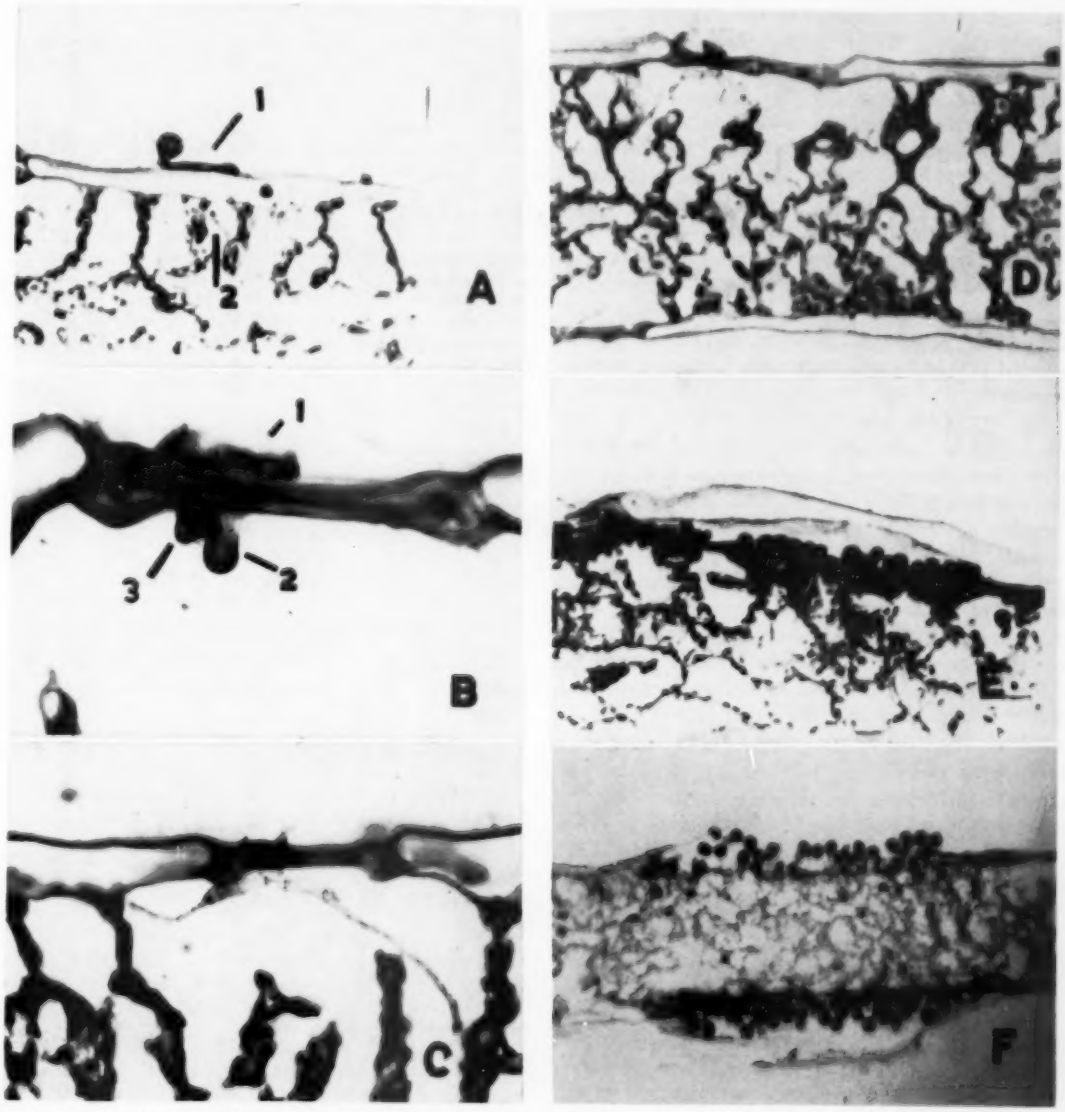


Fig. 2.—The developmental pattern of *Puccinia coronata* var. *avenae* in the highly susceptible Clinton 25 host. **A)** Germination of a spore upon the leaf epidermis; note the relative size of the germ tube (1) and the infection hypha (2) (×450). **B)** Two drained appressoria (1) persisting over a common stoma; the incipient substomatal vesicle (2) still resembles a pendulant ball while vesicle (3) is beginning to elongate (×1030). **C)** A partially drained substomatal vesicle and developing infection hyphae (×450). **D)** The extent of mycelial penetration arising from a single point of entry (×270). **E)** A massing weft of hyphae beneath the epidermis with abstricting urediospores (×270). **F)** Pustules with liberating urediospores (×138).

attaining the beginning of reproductive activity. However, isolated attempts were made by the fungus to form uredia. No dense welts of hyphae were found. Host tissue died rapidly and fungus growth was stopped after the formation of a few abortive urediospores. Damage to the host plant was not localized within the immediate area contiguous to the mycelium after 240 hours. Chlorosis or the complete disintegration of the chloroplasts, extended to whole areas of leaf tissue, at times engulfing the entire inoculated area of the seedling.

4) *Group IV.*—In Group IV the substomatal vesicles and the infection threads developing from them appeared to be quite granular. No nuclei could be distinguished within the infection threads. The protoplasmic contents of the infection hyphae were concentrated in the elongating tips. Forty-eight hours after inoculation, host cells in the immediate vicinity of the elongating, little-branched infection hyphae showed a clumping of the chloroplasts accompanied by shrinking of the cell walls. Development of haustoria appeared to be checked by a breakdown of the host tissue. In the vicinity of the substomatal cavity, areas of leaf tissue surrounded by vapid hyphae were reduced to dead, shriveled masses by 120 hours, although some infection hyphae penetrated deeper into the mesophyll. Maximum penetration of leaf tissue was attained by 144 hours. Only the elongating hyphal tips remained filled with protoplasm. The older portion of the mycelium was highly vacuolated. By 168 hours it could be seen that the spread of mycelium within the inoculated leaf had been checked by the collapse and plasmolysis of the host cells. Necrotic areas developed. In leaf sections examined at successive intervals up through 216 hours following inoculation, the distinctness and staining characteristics of the contents of the host cell had been so altered that the cell appeared to have completely degenerated. Sections through areas of the inoculated leaves in which the mycelium had not penetrated appeared normal 244 hours after inoculation.

Discussion.—In this investigation it was found that the entrance of the crown rust fungus into the oat leaf was similar in both the resistant and susceptible groups. Reaction between the host and parasite, however, differed once entrance was established. This is in accord with the findings of Ward (13) in his detailed histological investigation with *P. dispersa* on *Bromus* spp; of Marryat (8), working with *P. glumarum* on wheat; of Newton (9), on behavior patterns of *P. graminis tritici* in wheat; of Ruttle and Fraser (10), with *P. coronata* of oats; and of Wellensiek (15), working with *P. sorghi* of corn.

Although evidence of the true nature of resistance was not uncovered, the response of the host tissue invaded by the fungus from abrupt structural changes and death of the cells to the mutual survival of host and parasite is believed to indicate some inherent physiological or chemical attribute peculiar to the varieties themselves.

LITERATURE CITED

1. Bell, F. H. 1951. Distribution of hyphae of several plant-pathogenic fungi in leaf tissue. (Abstr.) Phytopathology. 41:3.

2. Bolley, H. L. 1908. Observations regarding the constancy of mutants and questions regarding the origin of disease resistance in plants. Am. Naturalist 42:171-183.

3. Cobb, N. A. 1890. Contributions to an economic knowledge of Australian rusts (Uredineae). Agr. Gaz. N. S. Wales 1:185-214.

4. Cross, G. L. 1937. An improved method of staining with fast green. Proc. Oklahoma Acad. Sci. 17:69-70.

5. Gibson, C. M. 1904. Notes on infection experiments with various Uredineae. New Phytologist 3:184-191.

6. Hitchcock, A. S., and M. A. Carleton. 1893. Preliminary report on rusts of grain. Kansas Agr. Expt. Sta. Bull. 38 p.

7. Johansen, D. A. 1935. Dehydration and infiltration. Science 82:253-254.

8. Marryat, D. C. E. 1907. Notes on the infection and histology of two wheats immune to the attacks of Puccinia glumarum, yellow rust. J. Agr. Sci. 2:129-138.

9. Newton, Margaret. 1922. Studies in wheat stem rust (Puccinia graminis tritici). Roy. Soc. Can. Proc. and Trans. (3) 16:(sect. 5) 153-210.

10. Ruttle, M. L., and W. P. Fraser. 1927. A cytological study of Puccinia coronata Cda. on Banner and Cowra 35 oats. Univ. Calif. Berkely Publs. Botany 14:21-72.

11. Stakman, E. C. 1914. A study on cereal rusts: Physiological races. Minn. Univ. Agr. Expt. Sta. Bull. 138. 56 p.

12. Stakman, E. C. 1915. Relation between Puccinia graminis and plants highly resistant to its attack. J. Agr. Research 4:193-200.

13. Ward, H. M. 1902. On the relations between host and parasite in the bromes and their brown rust, Puccinia dispersa (Erikss.). Ann. Botany. 16:233-315.

14. Ward, H. M. 1905. Recent researches on the parasitism of fungi. Ann. Botany. 19:1-54.

15. Wellensiek, S. J. 1927. The nature of resistance in Zea mays L. to Puccinia sorghi Schw. Phytopathology. 17: 815-825.

Authoritative RONALD books for plant pathologists . . .

DISEASES and PESTS of ORNAMENTAL PLANTS

PASCAL P. PIRONE, BERNARD O. DODGE, *Emeritus, and* HAROLD W. RICKETT
—all of the New York Botanical Garden

Complete and well organized, this standard reference guide includes all of the important ornamental plants of the United States. It embodies many years of experience and testing and the research results of leading plant pathologists and entomologists. Book provides a concise introduction to the problems of disease and pest control and tells why and under what conditions certain methods and substances should be used. *"A comprehensive guide . . . up to date."*—BIOLOGICAL ABSTRACTS. *3rd Ed., 1960. 775 pp., 221 ills.* $10

BLAKESLEE: The GENUS DATURA

AMOS G. AVERY, SOPHIE SATINA, *and* JACOB RIETSEMA
—all formerly Smith College Genetics Experiment Station

A full account of the genetic studies carried on for over forty years by Albert F. Blakeslee with several species of the genus *Datura.* This research constitutes one of the most thorough investigations ever made on a single group of plants—experiments and studies in the breeding, cytology, morphology, anatomy, physiology, embryology, geographical distribution, and evolutionary history of ten species in this genus. Includes the only known summary of the *Datura* nomenclature from 1753 to date. *"A rare and fascinating account of an important part of the history of cytogenetics."*—**Beal B. Hyde,** *in* BIOS. *Chronica Botanica: An International Biological and Agricultural Series, No. 20. 1959. 289 pp.; 317 ills., tables.* $8.75

VEGETABLE DISEASES and THEIR CONTROL

CHARLES CHUPP, *Emeritus, and* ARDEN F. SHERF
—both Cornell University

This book describes vegetable diseases and their control in a form which utilizes the extensive literature available and the authors' long teaching and practical field experience. The history, causes, and symptoms of each pathogen are grouped according to the plants they affect. There are separate chapters on the control of seed rot, damping-off, wire stem, and the general diseases which occur on many crops. Because mineral deficiencies in soils often produce symptoms that resemble pathogenic diseases, such deficiencies and their effects are discussed, as are nematodes and current practices in soil sterilization. *". . . complete, accurate, and practical."*—THE PLANT DISEASE REPORTER. *1960. 693 pp., 192 ills., tables.* $12

PRINCIPLES of PLANT PATHOLOGY

ELVIN C. STAKMAN, *Emeritus, University of Minnesota;*
J. GEORGE HARRAR, *The Rockefeller Foundation*

Written by two leading authorities, this comprehensive book explains the broad interrelationships between plants as economic resources and the diseases which limit their productivity. It relates general principles of phytopathology to the international distribution of plant pathogens, the etiology of major plant diseases, and fundamental considerations of international plant protection and disease control. Emphasis is placed upon epidemic diseases of food crops. *"Outstanding . . . the first presentation in book form of the international and humanistic aspects of plant pathology."*—**Kenneth F. Baker,** University of California. *1957. 581 pp.; 165 ills., tables.* $9

BIOLOGY and CONTROL of the SMUT FUNGI

GEORGE WILLIAM FISCHER, *Washington State University; and*
CHARLES STEWART HOLTON, *U. S. Department of Agriculture*

An exhaustive presentation—on a worldwide basis—of available knowledge about the smut fungi. Book covers historical aspects of the smut fungi; their phylogeny, morphology, and taxonomy. Describes the various techniques for research on the smuts; the effects of smuts on man, animals, and cultivated crops; and the control measures used to combat smut diseases. Includes a host family register of over 1,100 species of 33 genera with species catalogued by host family. *"Clearly written and well organized . . . indispensable to mycologists and plant pathologists."*—THE GARDEN JOURNAL OF THE NEW YORK BOTANICAL GARDEN. *1957. 622 pp.; 117 ills., tables.* $10

Publishers of CHRONICA BOTANICA BOOKS

Including: Chronica Botanica New Series of Plant Science Books — Chronica Botanica: An International Biological and Agricultural Series

THE RONALD PRESS COMPANY • 15 East 26th St., New York 10

TRIARCH PRODUCTS

FINE MICROSCOPE SLIDES FOR DISCRIMINATING BIOLOGISTS

As we prepare and sell only microscope slides, we are able to give you better quality, better service and better prices than you can get elsewhere.

Remember, TRIARCH means ACCURACY, DEPENDABILITY, SERVICE

Write for our new illustrated catalog No. 11a

GEO. H. CONANT **RIPON, WISCONSIN**

CONTROL
potato seed piece rot
up to 30 days with
PHYGON-XL

PHYGON®-XL is one of the most economical and effective fungicides for destroying fungi which attack unprotected seed potatoes in the ground. Phygon gives you better stands, higher yields, higher quality. Seed pieces won't rot up to 30 days after treatment, hence planting can be delayed in case of rain.

Phygon-XL is today's cheapest, most effective organic fungicide for the control of fungus diseases on fruit trees, row crops and ornamentals.

Order your Phygon-XL from your local supplier today. Write, wire or phone us if unable to locate immediate source of supply.

United States Rubber

Naugatuck Chemical Division

276 H Elm Street, Naugatuck, Connecticut

producers of seed protectants, fungicides, miticides, insecticides, growth retardants, herbicides: Spergon, Phygon, Aramite, Synklor, MH, Alanap, Duraset.

BIOLOGICAL ABSTRACTS

is growing with the literature

Because of the phenomenal growth in biological research papers published originally in thousands of journals throughout the world, an adequate abstracting and indexing service has become indispensable. *Biological Abstracts* searches out the significant contributions and publishes brief, yet informative, abridgments arranged according to subject matter. As well as the complete edition, it also is published in five comparatively low-priced sectional editions to meet the needs of individual biologists.

Section D (Plant Sciences) affords a very complete coverage of the research in plant diseases and related subjects. Priced at $35.00 for 24 semi-monthly issues less 20% to non-profit educational institutions, and 50% to individuals. The increase in subscription prices, due to an increase in coverage of more than 100% in four years, was necessary—but the cost per abstract to subscribers is lower than ever before.

BIOLOGICAL ABSTRACTS
University of Pennsylvania
Philadelphia 4, Pa.

On the occasion of the Golden Anniversary of the American Phytopathological Society, the Committee on Phytopathological Classics presents its tenth CLASSIC:

DEL MAL DEL SEGNO

by Agostino Bassi (1773-1856)

Translated into English from the Italian by P. J. Yarrow, University of Exeter

Edited, and with an introduction, by

G. C. Ainsworth, Commonwealth Mycological Institute, Kew

Bound in cloth $1.25

"The principle of pathogencity is now so familiar that it is difficult to appreciate the novelty of Bassi's work and to understand the opposition it aroused in some. Others accepted the discovery, which was a precursor of those made shortly afterwards by Schoenlein and by Gruby ('the father of medical mycology') of the mycotic nature of human ringworm, and it certainly influenced the Rev. M. J. Berkeley's findings on the cause of potato blight. . . . Bassi was a man of his time. He crystallized ideas that were becoming prevalent and by so doing assured for himself a place in the history of both medicine and plant pathology."—From the Introduction by G. C. Ainsworth.

"The importance of Bassi's work has to a great extent been overshadowed by that of Pasteur's a few years later but his genius deserves greater recognition than it has received. It was Bassi whose discoveries ushered in the dawn of the science of infectious disease. . . . Most writers of treatises and textbooks on infectious disease have yet to accord him the honor and credit he deserves."—From MICROBIAL CONTROL—THE EMERGENCE OF AN IDEA by E. A. Steinhaus.

Complete Sets of PHYTOPATHOLOGICAL CLASSICS
Numbers 1 through 10, including those numbers that until lately have been out of print . . . $10.50

Address orders with remittances to Robert S. Dickey, Treasurer, Department of Plant Pathology Cornell University, Ithaca, N. Y.

Phytopathological Classics

L. C. Knorr, Editor

A Publication of the American Phytopathological Society

NEWS

Editor: K. W. KREITLOW, Plant Industry Station, Beltsville, Md.

The Southern Division of the American Phytopathological Society will hold its annual meeting at Jackson, Mississippi, February 6-8, 1961 in conjunction with the 58th Annual Meeting of the Association of Southern Agricultural Workers.

Phytopathologist G. A. Gries, formerly Professor of Plant Physiology at Purdue University was recently appointed Head of the Department of Plant Pathology at the University of Arizona.

Plant pathologist Joseph Kuc will be on leave for the 1960-61 year to conduct research on the biochemical nature of plant disease resistance at the State Agricultural University, Wageningen, the Netherlands.

Phytopathologist S. M. Pady, Head, Department of Botany and Plant Pathology, Kansas State College, Manhattan, recently returned from England where he spent the summer working with Dr. P. H. Gregory, Head, Department of Plant Pathology, Rothamsted Experimental Station. Visits were also made to other laboratories in England and Wales.

A new division of the Society, to be known as the Caribbean Division, is being formed. This has been the culmination of efforts started in 1948, and a series of informal discussions among Caribbean-based members of the Society during various scientific meetings in the intervening years. The Caribbean Section of the American Society of Horticultural Science is inviting the Caribbean pathologists to meet with them March 26 to April 1, 1961, and while they are not in position to sponsor the establishment of the Caribbean Division A.P.S., they plan cooperative developments between the two Caribbean organizations. Interested Society members in countries and States in the United States of this region are asked to communicate with F. L. Wellman, Box 516, Rio Piedras, Puerto Rico, as soon as possible.

Professor Emeritus, E. C. Stakman is spending the fall months in Mexico at the invitation of the Post-Graduate College of the National School of Agriculture, Chapingo.

Plant pathologist R. L. Kiesling recently resigned from the Department of Botany and Plant Pathology, Michigan State University, East Lansing, to become Head of the Department of Plant Pathology, North Dakota Agricultural College, Fargo.

A recent graduate, Walter C. Mueller, has accepted a position as Assistant Professor of Plant Pathology, South Dakota State College, Brookings, where he will be engaged in research on virus diseases of cereals and legumes. Dr. Mueller received his degree from Cornell University. His research at Cornell was with A. F. Ross and W. F. Rochow and was concerned with the development and use of the aphid-injection technique in work with potato leafroll and barley yellow dwarf viruses.

Pathologists S. M. Pady and C. L. Kramer, Department of Botany and Plant Pathology, Kansas State University, Manhattan, have received a $13,800 U. S. Public Health Service grant to continue aerobiological studies.

Plant pathologist J. F. Fulkerson, formerly with the Forage and Range Research Branch, Crops Research Division, Beltsville, Maryland, has assumed responsibilities as principal plant pathologist with the State Experiment Stations Division, Washington, D. C.

Mycologist Mrs. Irma Gamundi de Amos, of Argentina, who is associated with the University of Buenos Aires, has left the National Fungus Collections for New York City, where she will continue her work at Columbia University.
Phytopathologist Philip J. Leyendecker is the new director of the New Mexico Extension Service. Dr. Leyendecker has been acting director since the death of Dr. Robert H. Black in April.

Recent appointments within the Department of Plant Pathology, Cornell University include: Phytopathologists Kenneth D. Hickey and Durward F. Bateman, and Entomologist Carlton S. Koehler. Dr. Hickey, a graduate of Pennsylvania State University, will carry on extension work in tree fruit diseases; Dr. Bateman, a Cornell graduate, will study the physiology of fungi, particularly those responsible for root diseases; and Dr. Koehler, a Cornell graduate will conduct extension work on small fruit insects and diseases, as well as handle the entomology and plant pathology programs for pre-adult groups in New York.

THE PRESIDENT'S COLUMN

At the Green Lake meeting a number of innovations and changes were introduced into the operational procedures of our Society with the general objective of promoting a better exchange of phytopathological information.

The greatest change is in committee structure and programming of the annual meetings. This change has been instituted on the recommendation of an ad hoc committee headed by Glenn Pound. In order to build an annual program around the subject matter fields of major interest to the Society, the Program Committee has been reconstituted. It will be composed of the chairman of a series of subject matter committees. The Program Committee thus became a super committee of the Society. Its chairman will be the President-Elect. The nine subject matter groups presently represented will be: Bacteriology, Chemical Control, Disease and Pathogen Physiology, Epidemiology and Meteorology, Host Resistance and Microbial Genetics, Mycology, Plant Nematology, Plant Virology, and Soil Microbiology. Additional representation will be given by the chairmen of four of the general Standing Committees, namely Extension, Industry, Public Relations, and Teaching. This committee of 15 members (the Secretary is also included), will plan the programs of the annual meetings several years in advance. Continuity will be maintained by having the chairman of the subject matter committees serve for more than one year. It is hoped that the interest of the programs and efficiency in planning will be much increased by having direct access to the various subject matter fields. Greater emphasis will be given to the programming of symposia, invitational research papers and conferences by workers in limited research areas. As far as possible the contributed paper sessions will be organized around the basic subject matters rather than on a crop division. We believe this to be a necessity if our science of phytopathology is to grow and keep abreast of advances in the other sciences.

Furthermore, it is planned to sponsor limited programs apart from our annual meetings, with appropriate groups such as the American Institute of Biological Sciences, and the American Association for the Advancement of Science. These various expanded activities will naturally require additional financing. Thus, the Program Committee has been provided with a sizeable budget to carry out these worthwhile plans.

In the field of publications significant changes in objectives and hence in committee structure also have been made. The chairman of a series of subcommittees will constitute the new overall Publications Committee. The submittees are: Phytopathology, i.e., the Editorial Board of Phytopathology, Phytopathological Classics, Phytopathological Reviews and Monographs, Phytopathological News, and New Fungicide and Nematocide Data. Plans are now under consideration for a possible new approach to the Reviews and Monographs which for over a decade have been unable to get off the ground. The "News" initiated by K. W. Kreitlow, 12 years ago, is to be enlarged to provide more coverage pertaining back to our members and to plant pathology in general.

Finally on the recommendation of a special committee to study Publications and Public Relations chairmanned by J. G. Horsfall we have instigated a column by the President. This constitutes the first-born. Here, the President may editorialize or otherwise focus the attention of the members on matters of policy or issues deemed of interest. Fortunately for us all, guest contributors also may be invited.

We believe in a democratic Society. To provide our members with a rostrum we heartily agree to the suggestion for a second column in Phytopathology for "Letters to the Editor." We invite you to use it to the fullest extent.

INDEX

For Volume 50

INDEX FOR VOLUME 50

AUTHOR AND SUBJECT INDEX. Junior authorship is indicated by page numbers in parentheses. Page numbers of illustrations are in bold face. A special listing is made of "new species, varieties, etc."

abstracts
APS, 1960 627
Northeastern Division of APS, 1959, 239
Pacific Division of APS, 1959 82
Potomac Division of APS, 1960 569
Southern Division of APS, 1960 574
aeromycology
smuts in Kansas 332
Afanasiev, M. M. (574)
Akai, Shigeyasu 687
Albert, J. J. (571)
Alexander, Leonard J. 627
alfalfa
Aphelenchoides ritzema-bosi in, culturing, histopathology, and biochemistry 643
Ascochyta imperfecta from, host range, pathogenicity, and taxonomy 105
Cephalosporium in, associated with root rot 241
Corynebacterium insidiosum in
pathogenicity and stability of strains 377, **378**
rapid screening for resistance 637
Ditylenchus dipsaci in, culturing, histopathology and biochemistry 643
Leptodiscus terrestris in, host-parasite relations 416, **417**
419
Meloidogyne hapla in, effect on growth 181
Meloidogyne incognita in, effect on growth 181
Phoma herbarum medicaginis in, effect of temperature on black stem 628
Pratylenchus pratensis in, effects of nematocides on nematode and host yields 656
Pseudopeziza medicaginis in, screening for resistance 568
residues of, effect on soil fungi 22
root rot, associated with Cephalosporium 241
seedling blight, effect of growing crops and crop residues on 22
sensitive to atmospheric ozone 639
Xiphinema americanum in, only known Dorylaimoidea with in New York 658
Allen, T. C., Jr. (847)
Allington, W. B. 627
almond
Rhizopus in
fumaric acid determination 646
role of fumaric acid in hull rot 646
Sclerotinia in, relative pathogenicity of S. fructicola and S. laxa 550, **556**
Al-Sohaily, Ibrahim A. 627, 627
Ambrosia artemisifolia, tobacco ringspot virus in, isolated from symptomless host 296
Amphorophora rubi, vector of the two viruses in raspberry mosaic 570
Andersen, Arne S. 627
Anderson, C. D. (655)
Anderson, C. W. (73)
angular leafspot, see under **strawberry**
annual meeting APS, 1959, proceedings 242
antigenic analysis, extracts from healthy plants 646
antisera, plant-virus, commercially produced, serological studies of 428
Aphis helichrysi, vector of radish yellows virus 389, **391**
apple
Alternaria in, symptoms and species 657
Botryosphaeria in, control with lead arsenate 571
Botryosphaeria ribis in
enzymes hydrolyzing cell wall polysaccharides 258
physiological factors affecting susceptibility 91
relation to rot 394, **397**
Ceratocystis fagacearum in, susceptibility of several varieties 177
apple (continued)
Gloeodes pomigena in, morphological and nutritional differences of isolates 571
Glomerella cingulata in, physiological factors affecting susceptibiltiy 91
Neofabraea malicorticis in, physiological factors affecting susceptibility 91
Physalospora obtusa in, physiological factors affecting susceptibility 91
Podosphaera leucotricha in, biochemical response of host 844
Pratylenchus penetrans in, seedling growth in response to inoculation 237
stem-pitting virus in, bark patch grafts for indexing 241
Venturia inaequalis in, biochemical response of host 844
viruses in, a sensitive indicator apple clone 646
apricot
Sclerotinia in, relative pathogenicity of S. fructicola and S. laxa 550, **556**
virus-caused stunt of, relation to other stonefruit viruses 658
Ark, Peter A. (182)
Arnold, W. N. 578
Arny, D. C. (290), (641)
Asai, G. N. 535
Ashley, T. E. (576)
Ashworth, Lee J., Jr. 627
Atkin, J. D. (241)
Averre, C. W., III 627
Averre, Charles W., III (654)
avocado
Phytophthora cinnamomi in,
attraction of zoospores by roots 660
methods of isolation 87
soil fungicides for prevention and therapy 660
Aycock, Robert 574
azalea, Ovulinia azaleae in, control with thiram 576
bacteria
new bacterium
cause of hairy root of field roses 647
Corynebacterium insidiosum
in alfalfa
rapid screening for resistance 637
pathogenicity and stability of strains 377, **378**
Erwinia, in chicory, effect on electrical conductance 272
Erwinia amylovora, culture media for viability studies and storage 685
Erwinia chrysanthemi, in Dieffenbachia, associated with bacterial stem rot 696, **697**
Erwinia cypripedii, in orchid, cause of bacterial brown rot 182
Erwinia tracheiphila, culture and storage characteristics 179
Pseudomonas in chicory, effect on electrical conductance 272
in fruit, isolates associated with blast and canker 84
in lily, antagonism and synergism with other organisms 615, **616, 618**
Pseudomonas andropogonis, in corn, apparent cause of unreported bacterial stripe 906, **907, 908**
Pseudomonas caryophylli, in carnation, disease control by culture-indexing 356, **358**
Pseudomonas fluorescens, antagonism to Pseudomonas phaseolicola and other bacteria 119, **122**
Pseudomonas pastinacae, new bacterium, cause of bacterial brown rot of parsnip roots 280, **281**
Pseudomonas phaseolicola, antagonism by Pseudomonas fluorescens 119, **122**
Pseudomonas solanacearum

bacteria Pseudomonas solanacearum (continued)
is banana, strains in Costa Rica and relation to bacterial wilt of banana 660, **662, 663**
in Heliconia, relation to bacterial wilt of banana 660, **662, 663**
in Physalis angulata, relation to bacterial wilt of banana 660, **662, 663**
in soil, in Costa Rica 654
in tobacco
oxidation rates of polyphenols and ascorbic acid in stem tissue 645
virulence from avirulent-virulent mixtures 627
in tomato, relation to bacterial wilt of banana 660, **662, 663**
Pseudomonas syringae
in cherry, susceptibility of mazzard seedlings 82
in stone fruits, source of the inoculum 634
isolates pathogenic on stone fruits, relationships among 889, **891-893, 895-897**
Pseudomonas tabaci
in tobacco
behavior of resistance locus in Burley 21 and Ky 61 770
population studies in plants of varying resistance 655
Xanthomonas campestris, in crucifers, control with antibiotics 642
Xanthomonas vesicatoria
in pepper
effect of fertilization 577
screening for resistance 577
variability in Florida 657
in tomato
influence of temperature and host age and nutrition 360
physiology of bacterial spot 648
variability in Florida 657
bacterial spot, see (under **tomato**) **Xanthomonas vesicatoria**
bacterial stem rot, in Dieffenbachia, Erwinia chrysanthemi associated with 696, **697**
Bagnall, R. H. 460
Baigent, Nancy L. 82
Baker, Kenneth F. 82
Baker, Ralph (356)
Bald, J. G. 497, (578), 615, 628
Baldwin, Robert E. 569
banana
Cercospora musae in, control with oil sprays timed to disease cycle 488, **490**
Fusarium in, physical barriers in relation to resistance 628
Fusarium cubense in, role of pectic enzymes in resistance 635
Fusarium lycopersici in, role of pectic enzymes in resistance 633
Mycosphaerella musicola in
fungistasis by petroleum oil 865
precision spray technique for evaluating control with oils 69, **71**
nematode-free seed, preparation of 383, **384**
Pseudomonas solanacearum in, strains in Costa Rica and relation to bacterial wilt of banana 660, **662, 663**
Bancroft, J. B. 34, (643), 711
Banfield, Walter M. 628
barberry, Puccinia graminis tritic near, survival on wheat 40
barley
barley stripe mosaic virus in
effect of temperature and host age on disease and seed infection 290, **292**
effect of temperature on concentration 641
Erysiphe graminis hordei in
genes conditioning pathogenicity 647
genotypes of host and pathogen 736
inheritance of 5 genes conditioning pathogenicity 647
extracts from healthy plants, antigenic analysis 646
Helminthosporium gramineum group in, morphology, physiology, and pathology 688
barley (continued)
Helminthosporium sativum in, evaluating resistance by lesion type 632
hoja blanca virus in, transmission by Sogata orizicola 643
loose smut in, preparing embryos for examination 270
Meloidogyne javanica in, effect of host on nematode population level 657
Puccinia coronata avenae in, induced susceptibility to 630
Puccinia graminis avenae in, induced susceptibility to 630
Rhynchosporium secalis in, variations in pathogenicity 642
Septoria passerinii in, role of straw in epiphytology 910, 911
Ustilago nuda in, detecting viable mycelium after seed treatments 647
Barnes, E. H. 844
Barnes, George 574
Barnett, H. L. (655)
Bart, George J. 177
Barton, D. W. (654)
Bateman, D. F. 628
bean
alfalfa mosaic virus in, new strain, vein necrosis 226, **229**
Erysiphe polygoni in, inhibition by antibiotic produced by Streptomyces sp. 841
multiple-disease-resistant variety, Great Northern 1 140 574
peach ringspot virus in, topical susceptibility 659
peach yellow bud mosaic virus in, topical susceptibility 659
possible new virus in, wide host range 655
Rhizoctonia solani in, effects of decomposing green plant materials and associated microfloras 516, **518**
rust in
effect of postinoculation temperatures 653
local necrosis associated with 653
severe bean mosaic virus in
a new virus from Mexico 334, **335, 336**
interaction with potassium gibberellate 525, **526**
Thielaviopsis in, influence of pH on root rot 628
tobacco mosaic virus in, localized acquired resistance 741, **742**
tobacco necrosis virus in
topical susceptibility 659
topical susceptibility to cowpea strain 659
bean strain, release and preservation by roots 111
top necrosis virus in, thought to be strain of tobacco ringspot 576
Uromyces phaseoli typica in, nature and turnover of organic acids in 643
vein necrosis virus in, new strain of alfalfa mosaic virus 226, **229**
Bean, George A. 628
Beck, G. E. (652)
Beckman, C. H. 628
Bega, Robert V. 61, 628
Bell, A. A. 629
Benda, G. T. A. 629
Benson, A. P. 231, 629
bentgrass, Seaside, Rhizoctonia solani in, effect of nutrition, pH, and soil moisture 532
Beraha, Louis 474
Berger, C. (631)
Berry, Robert W. 629
Berry, S. Z. 298, 569
Bingham, David J. (649)
birch, salt injury 240
Birchfield, W. 629
birdsfoot trefoil
Leptodiscus terrestris in
host-parasite relations 416, **417, 419**
Xiphinema americanum in,
only known Dorylaimoidea with in New York 658
Blaak, G. (649)
Black, D. S. (129)
Bloom, James R. (319), 532, (761)
Bloss, H. E. 569
Bloss, H. W. (570)

blossom end rot, of tomato, effect of calcium and molybdenum 655
blueberry
necrotic ringspot virus in, cause of new disease 241
postharvest decay, effect of temperature 241
stunt virus in, wild sources in New Jersey 308, **310, 311**
boll rot, of cotton, organisms causing at various temperatures 653
Bollenbacher, Katharina (575)
book listings 90, 238, 328, 402
Boosalis, M. G. 629
Boosalis, Michael G. 860
Boothroyd, C. W. 239
Boyce, John S., Jr. 775
Bozarth, Robert F. (652)
Bradley, R. H. E. (649)
Brakke, Myron K. 629
Brase, K. D. (240)
Braun, Alvin J. 239
Braun, Armin C. (324)
Braverman, Samuel W. 688, 691
Brennan, E. (239), (570)
Brennan, Eileen (186)
Brevicoryne brassicae, vector of cabbage virus B, site of carriage of virus 649
Brierley, Philip 404, 569
Brinkerhoff, L. A. (673)
broccoli
Peronospora parasitica in
inheritance of resistance 241
role of oospores in downy mildew 93, **94**
Brodie, Bill B. 673
bromegrass, smooth, seedling blight of, influence of soil temperature and fungi present 1
broomrape, seed stimulation with gibberellic acid 772, **773**
Brown, C. M. (84)
Brown, Irwin F. 830
Brown, Irwin F., Jr. 569
Brown, R. E. 630
Brown, R. T. (577), (655)
Brown, William M., Jr. (649)
Browning, J. Artie 630, 630
Brun, W. A. (69)
Buchanan-Davidson, D. J. (198)
Buddenhagen, Ivan W. 660
bunchy top, of tomato, with crease stem 577
Burchfield, H. P. (656)
Burchfield, Harry P. (573)
Burke, D. W. (655)
Burkholder, Walter H. (119), 179, 280
Butler, Edward E. 665
cabbage
Fusarium oxysporum conglutinans in
oxidative enzymes in host 370
proteins in host 198, **201, 202**
Peronospora parasitica in, role of oospores in downy mildew 93, **94**
cabbage yellows, see (under cabbage) **Fusarium oxysporum conglutinans**
Cairns, Eldon J. (576), (576), (784)
Caldwell, Ralph M. 630, (654)
Calpouzos, L. 69, (657), 865
Caltrider, Paul G. 630
Calvert, Oscar H. 136
Cameron, H. Ronald 82, 630
Campbell, R. N. 631
cantaloupe
curly top virus in, losses from late infection 327
guttation, leaf injuries associated with 640
Cappellini, R. A. (163)
Carlson, Lester W. 574, 822
carnation
Criconemoides curvatum in
observation box for on living roots 573
parasitism and pathogenicity 656
carnation (continued)
Fusarium oxysporum dianthi in
disease control by culture-indexing 356, **358**
influence of nitrogen and potassium nutrition 636
Fusarium roseum cerealis in, histochemical and morphological studies 651
Pseudomonas caryophylli in, disease control by culture-indexing 356, **358**
carrot, Ceratocystis fimbriata in, fungitoxic compound isolated from tissue 267
Carter, H. E. (594)
Carver, R. G. 575
castorbean
Pythium in, relations of variety, temperature, and seed immaturity to pre-emergence damping-off 473
Verticillium albo-atrum in, symptoms of wilt 85
cedar (eastern red)
Merulius lacrymans in, effects of environment on growth 633
Phomopsis juniperovora in, survival in the nursery 639
celery
bacterial petiole spot of, caused by possibly new bacterium 648
Cercospora apii in, inoculum production and seedling evaluation 605
cereals
Helminthosporium avenae in, morphology, physiology, and pathology 688
Helminthosporium bromi in, morphology, physiology, and pathology 688
Helminthosporium gramineum in, morphology, physiology, and pathology 688
Helminthosporium phaeocomes in, morphology, physiology, and pathology 688
Helminthosporium teres in, morphology, physiology, and pathology 688
Pleospora phaeocomes in, Helminthosporium stage of 688
cereals (winter), Meloidogyne javanica in, effect of cereals on population level 657
Cetas, R. C. (635)
Chaiet, L. (841)
Chamaecyparis thyoides, Sclerotium bataticola and Fusarium in, immune to black root rot 653
Changsri, Winit 631
Chapman, Richard A. 181, 631
Chapman, W. H. (576)
Chattopadhyay, S. B. 434, 439
chemicals
acetic acid, on Cladosporium cucumerinum, toxicity of 781
achromycin, on Xanthomonas campestris, treatment of seed of crucifers 642
Acti-dione, on 10 fungi spp. concentration for inhibition 870
agrimycin, on Xanthomonas campestris, treatment of seed of crucifers 642
Albamycin, on 10 fungi spp. concentration for inhibition 870
alcohols, on peach fruit-rotting fungi, effect on spores 790
amino acids
in cherry leaves, effect of mottle leaf and rasp leaf viruses 141
in peach leaves, effect of Western X-disease and ringspot virus 141
in Prunus mahaleb leaves, effect of ringspot virus 141
ammonia, in packages of oranges, effect on blue-green mold decay 855
Amobam, on Fusicladium effusum, very poor control on pecan 574
antibiotics
antifungal produced by actinomycetes, enrichment method for isolating 88, **88**
P-9, against Puccinia graminis tritici in wheat, half-life of 627
Pimaricine, effect on several cacao fungi in vitro 638
produced by Pullularia pullulans, activity of 82

chemicals, antibiotics (continued)
produced by strain of Streptomyces griseus, partial purification and biological activity 169, 171
antimetabolites
5-phenylazopyrimidines, effect on multiplication of tobacco mosaic virus 344
pyrimidines, effect on multiplication of tobacco mosaic virus 344
Aramite
on Diplocarpon rosae, for control in rose 573
on Tetranychus telarius, for control in rose 573
Aureomycin
on 10 fungi spp. concentration for inhibition 870
on Xanthomonas campestris, treatment of seed of crucifers 642
8-azaguanine, on tobacco mosaic virus, effects on replication 884
B.22555, on 10 fungi spp. concentration for inhibition 870
B-856, on 10 fungi spp., concentration for inhibition 870
biphenyl, in packages of oranges, effect on blue-green mold decay 855
Bordeaux mixture, on Fusicladium effusum, control on pecan 574
boron, effect on mango necrosis 431
C-272, on 10 fungi spp., concentration for inhibition 870
calcium sulphate, on cotton seed, effect on terminal breakdown 658
captan
on Diplocarpon rosae, for control in rose 573
on 10 fungi spp., concentration for inhibition 870
on lily bulbs, root rot control in combination with pentachloronitrobenzene 636
on Neurospora sitophila, interaction with functional enzymes in conidia 649
on snapdragon rust, effect of temperature 242
on strawberry
effect of Botrytis cinerea and other organisms 657
for control of Botrytis cinerea 491, **492**, **493**
on Tetranychus telarius for control in rose 573
wheat seed treatment, effect on germination and yield 635
Catechol, on 10 fungi spp., concentration for inhibition 870
Ceresan M, with DDT, rye seed treatment for Helminthosporium sativum and Sitophilus oryzae 576
Ceresan 100
on Pythium ultimum and Rhizoctonia solani in cotton and sugar beet, selective protection 643
with malathion, rye seed treatment for Helminthosporium sativum and Sitophilus oryzae 576
cerium, uptake by fungi, relation to lipid content of conidia 646
chelators, reversal of fungitoxicity of 8-quinolinol 421
Chemagro D-113, on Sclerotium rolfsii, control in tomato 578
chloranil, on snapdragon rust, effect of temperature 242
5-chloro-4-phenyl-1,2-dithiol-3-one, on Monilinia fructicola and Alternaria oleracea high degree of fungitoxicity 650
5-chloro-4(p-tolyl)-1,2-dithiol-3-one, on Monilinia fructicola and Alternaria oleracea, high degree of fungitoxicity 650
colletotin, toxin produced by Colletotrichum fuscum 325, **326**
copper
associated with a leaf spot of holly 84
on Colletotrichum capsici, effect on oxygen use and amino acid and sugar content 680
on snapdragon rust, effect of temperature 242
cycloheximide, against Puccinia graminis tritici, in wheat, half-life of 627
cycloheximide semicarbazone, on cucumber, bioassay of systemic activity 795
Cyprex, on Fusicladium effusum, control on pecan 574
Cytovirin, effects on susceptibility and transmissibility of potato virus Y in pepper 109

chemicals (continued)
D-D
on nematodes, effect on occurrence in field bins 576
on Pratylenchus pratensis, effects on nematode and alfalfa yields 656
DDT, with Ceresan M, rye seed treatment for Helminthosporium sativum and Sitophilus oryzae 576
Delsan A-D, rye seed treatment, for Helminthosporium sativum and Sitophilus oryzae 576
demeton
on Diplocarpon rosae for control in rose 573
on Tetranychus telarius for control in rose 573
Diazinon, on Pratylenchus penetrans, elemination from roots of cherry 654
Dibam, on Fusicladium effusum, very poor control on pecan 574
1,2-dibromo-3-chloropropane
on Criconemoides, control with rose root dip treatments 659
on Pratylenchus, control with rose root dip treatments 659
on Pratylenchus pratensis, effects on nematode and alfalfa yields 656
dichlone
on Neurospora sitophila, interaction with functional enzymes in conidia 649
uptake by fungi, relation to lipid content of conidia 646
dichloroisocyanuric acid, control of Penicillium digitatum in citrus 83
dieldrin, wheat seed treatment, effect on germination and yield 635
O,O-diethyl-S-(ethylthiomethyl) phosphorodithioate
on Criconemoides, control with rose root dip treatments 659
on Pratylenchus, control with rose root dip treatments 659
with Pratylenchus penetrans, effects on populations 640
O,O-diethyl-0-2-pyrazinyl phosphorothioate
on Belonolaimus longicaudatus, control in peanut 632
on Criconemoides, control with rose root dip treatments 659
on Pratylenchus, control with rose root dip treatments 659
on Pratylenchus vulnus 654
Dimethoate, on Pratylenchus vulnus, elimination from roots of rose 654
p-dimethylaminobenzenediazo sodium sulfonate
on Phytophthora cinnamomi, prevention and therapy in avocado 660
on Pythium ultimum and Rhizoctonia solani in cotton and sugar beet, selective protection 643
properties, effect of light on 639
with sugar beet, uptake and translocation by seedlings 639
diribonucleic acid, on Prunus, content of leaf tissue 630
dithiocarbamate, mono- and dialkyl N-substituted, comparative fungitoxicity 641
n-dodecyl guanidine acetate
on fungus conidia, uptake and innate toxicity 646
on Monilinia fructicola, mechanisms of fungitoxic action 830
on Saccharomyces pastorianus
effect on enzymes of 569
mechanisms of fungitoxic action 830
uptake by fungi, relation to lipid content of conidia 646
Dowfume W-85, on nematodes, effect on occurrence in field bins 576
Dowicide B, on Meloidogyne incognita acrita, control on gladiolus 574
Duramycin, on 10 fungi spp., concentration for inhibition 870
Dyrene
on 10 fungi spp., concentration for inhibition 870
on Fusicladium effusum, control on pecan 574

chemicals (continued)
EN 18,133, on Meloidogyne incognita acrita, control on gladiolus 574
enzymes, systems analyzed in Ditylenchus triformis, D. dipsaci, and Pratylenchus zeae 9
ethanol, production of by Thielaviopsis 632
ethyl acetate, production of by Ceratocystis fimbriata planti and Thielaviopsis 632
ferbam
on Diplocarpon rosae for control in rose 573
on Tetranychus telarius for control in rose 573
filipin, inhibition of 77 fungi 594, **595-598**
formalin, on Meloidogyne incognita acrita, control on gladiolus 574
fumaric acid, produced by Rhizopus, role in hull rot of almond 646
fumigants, concentrations, automatic measurement 642
fungicides, on Tilletia caries, vapor action ineffective in wheat seed treatment 581
gallic acid, on 10 fungi spp., concntration for inhibition 870
glyodin
on Colletotrichum capsici, effect on oxygen use and amino acid and sugar content 680
uptake by fungi, relation to lipid content of conidia 646
1,1,1,3,3,3-hexachloro-2-propanol, with fungi, action on sporulation 640
ionized, effect of charge on translocation through xylem 239
isobutyl acetate, production of, by Ceratocystis fimbriata planti 632
Karathene on 10 fungi spp., concentration for inhibition 870
lead arsenate, on Botryosphaeria, control in apple 571
malathion
on Diplocarpon rosae, for control in rose 573
on Tetranychus telarius, for control in rose 573
with Ceresan 100, rye seed treatment for Helminthosporium sativum and Sitophilus oryzae 576
maneb
on Cercospora kikuchii, control on soybean seed 570
on Colletotrichum capsici, effect on oxygen uptake in presence of substrates found in oxidative pathways 572
on Diaporthe phaseolorum sojae, control on soybean seed 570
on Diplocarpon rosae for control in rose 573
on Rhizoctonia fruit rot of tomato, control tests in laboratory, greenhouse, and field 570
on Tetranychus telarius for control in rose 573
MC-2, on nematodes, effect on occurrence in field bins 576
mercuric chloride, on Xanthomonas campestris, treatment of seed of crucifers 642
mercury
on cotton seed, effect on terminal breakdown 658
uptake by fungi, relation to lipid content of conidia 646
methyl arsine sulfide, on Pythium ultimum and Rhizoctonia solani, in cotton and sugar beet, selective protection 643
methyl bromide, on Colletotrichum fragariae, control in strawberry 575
milk, effect on tobacco mosaic virus 638
Mycostatin, on 10 fungi spp., concentration for inhibition 870
Mylone, on Sclerotium rolfsii, control in tomato 578
nabam
action on Fusarium oxysporum cubense 83
sorption in soil 83
β-naphthalene acetic acid, on strawberry, effect on Botrytis cinerea and other organisms 657
Nemagon
on Meloidogyne incognita acrita, control on gladiolus 574
on nematodes, effect on occurrence in field bins 576
on Pratylenchus vulnus 654
neomycin, on 10 fungi spp., concentration for inhibition 870
chemicals (continued)
New Improved Ceresan, on Meloidogyne incognita acrita, control on gladiolus 574
nickel chloride
on Puccinia graminis tritici in wheat, half-life of 627
effect on development of infected plants 640
nickel dioctyl sulfo succinate, against Puccinia graminis tritici in wheat, half-life of 627
nickel salts, on Puccinia menthae, control in mint 866
nystatin, toxicity to spores of Botrytis, Diplodia tubericola, Monilinia fructicola, and Rhizopus 163
oil sprays, timed to disease cycle to control Cercospora musae in banana 488, **490**
Orthocide Seed Protectant, rye seed treatment, for Helminthosporium sativum and Sitophilus oryzae 576
Ortho-dibromo 8, on Pratylenchus vulnus, elimination from roots of rose 654
ozone
cause of plant injury 639
on spinach, leaf spotting resulting 570
P-9, antibiotic produced by a Streptomyces sp. 841
Panogen, on Pythium ultimum and Rhizoctonia solani in cotton and sugar beet, selective protection 643
pentachloronitrobenzene
on lily bulbs, root rot control in combination with captan 636
on Pythium ultimum and Rhizoctonia solani in cotton and sugar beet, selective protection 643
on 10 fungi spp., concentration for inhibition 870
petroleum oil on Mycosphaerella musicola, fungistasis in banana leaves 865
phorate
on Diplocarpon rosae for control in rose 573
on Tetranychus telarius for control in rose 573
Phosphamidan on Pratylenchus vulnus, elimination from roots of rose 654
Pimacrin on 10 fungi spp., concentration for inhibition 870
potassium gibberellate, interaction with severe bean mosaic virus in bean 525, **526**
propylene oxide, sterilization of agar media 868
2-pyridinethiol-1-oxide, systemic disease control with 239
pyrogallol on 10 fungi spp., concentration for inhibition 870
quaternary ammonium chemotherapeutants, controlling translocation with cations and solvents 634
8-quinolinol, fungitoxicity, reversal by amino acids and other chelators 421
Rimocidin on 10 fungi spp., concentration for inhibition 870
rose bengal, on 10 fungi spp., concentration for inhibition 870
semicarbazone of cycloheximide against Puccinia graminis tritici in wheat, half-life of 627
silver, uptake by fungi, relation to lipid content of conidia 646
sodium metabisulfate on 10 fungi spp., concentration for inhibition 870
sodium pentachlorophenoxide on Sclerotinia laxa and S. fructicola, effect of combination with lime-sulfur 649
streptomycin
absorption by hops as affected by Pseudoperonospora humuli 278, **278**
absorption, translocation, and retention in hops 351
on 10 fungi spp., concentrations for inhibition 870
on Xanthomonas campestris, treatment of seed of crucifers 642
uptake by foliage, influence of cation competition, time, and temperature 851
sulfur
on snapdragon rust, effect of temperature 242
rusty spot of peach, effective control 239
uptake by fungi, relation to lipid content of conidia 646
tannic acid on 10 fungi spp., concentration for inhibition 870
Telone, on nematodes, effect on occurrence in field bins 576
Terrachlor on Sclerotium rolfsii, control in tomato 578

chemicals (continued)
terramycin on Xanthomonas campestris, treatment of seed of crucifers 642
tetrin, new antifungal antibiotic, produced by Streptomyces sp. 817
thimet on Pratylenchus, elimination from roots of rose, orchid, and cherry 654
thiram
on 10 fungi spp., concentration for inhibition 870
on Glomerella cingulata, resulting degradation of thiram 651
on Ovulinia azaleae, control in azalea 576
Thujaplicin on 10 fungi spp., concentration for inhibition 870
tribasic copper sulphate
on Cercospora kikuchii, control on soybean seed 570
on Diaporthe phaseolorum sojae, control on soybean seed 570
on Rhizoctonia fruit rot of tomato, control tests in laboratory, greenhouse, and field 570
N-trichloromethylthiophthalimide, on Rhizoctonia fruit rot of tomato, control tests in laboratory, greenhouse, and field 570
O,O,O-trimethyl phosphorothioate, on Phytophthora cinnamomi, prevention and therapy in avocado 660
ustilagic acid on 10 fungi spp., concentration for inhibition 870
Vapam
on Meloidogyne incognita acrita, control on gladiolus 574
on Sclerotium rolfsii, control in tomato 578
victoxinine, isolation technique from cultures of Helminthosporium victoriae 324
zineb
on Cercospora kikuchii, control on soybean seed 570
on Diaporthe phaseolorum sojae, control on soybean seed 570
on Diplocarpon rosae for control in rose 573
on Fusicladium effusum, control on pecan 574
on snapdragon rust, effect of temperature 242
on 10 fungi spp., concentration for inhibition 870
on Tetranychus telarius for control in rose 573
ziram on Fusicladium effusum, very poor control on pecan 574
Chenopodium hybridum, assay host, for bromegrass mosaic virus 632
Chenopodium murale, tobbaco mosaic virus in, field occurrence 628
Cheo, P. C. (884)
cherry
Cucumber mosaic virus in, juice transmission to 85
dead button in, a nontransmissible disorder, symptoms 87
green ring mottle virus in, cause of epinasty reaction 495, **496**
little cherry virus in, reservoir in flowering cherry 188
mottle leaf virus in, effect on free amino acids and amides 141
necrotic ringspot virus in, pollen transmission 624
Pratylenchus in, elimination from roots with thimet 654
Pratylenchus penetrans in, elimination from roots with diazinon 654
prune dwarf virus in, pollen transmission 624
Pseudomonas syringae in, susceptibility of mazzard seedlings 82
rasp leaf virus in, effect on free amino acids and amides 141
ringspot virus in
effect on free amino acids and amides 141
effect on yields 412
separated from green ring mottle virus 495, **496**
yellows virus in, effect on yields 412
chestnut (Chinese), Merulius lacrymans in, effects of environment on growth 633
chestnut (Japanese), Merulius lacrymans in, effects of environment on growth 633
Chi, C. C. 631, 631
chicory
Erwinia in, effect on electrical conductance 272
Pseudomonas in, effect on electrical conductance 272
Chidester, J. L. (82)
Chitwood, B. G. 631
Chiu, Ren-jong 632
Christensen, Clyde M. (703)
chrysanthemum, mosaic virus in, heat treatment 404, **406**
citrus
Meloidogyne in, in Taiwan and New Delhi 631
Penicillium digitatum
ammonia-generating formulations for control in fruit 634
control with dichloroisocyanuric acid 83
Phytophthora in, separating isolates pathogenic to 83
Phytophthora citrophthora in, girdling to reduce size of gummosis lesions 83
Phytophthora parasitica in, girdling to reduce size of gummosis lesions 83
Thielaviopsis basicola in, pathogenicity and isolation from field roots 86
Clark, D. G. (239)
Clayton, C. W. (653)
cleome
tobacco necrosis virus in
release and preservation by roots 111
topical susceptibility 659
clover
Ascochyta caulicola in, cause of stem disease 643
Heterodera trifolii in, in leaves 866, **867**
Mycosphaerella davisii in, cause of stem disease 643
Mycosphaerella lethalis in, cause of stem disease 643
stem diseases, incited by Mycosphaerella lethalis, M. davisii, and Ascochyta caulicola 643
tobacco ringpot virus, isolated from symptomless host 296
wound-tumor virus in, biochemical studies of the root tumors 651
Xiphinema americanum in, only known Dorylaimoidea with in New York 658
clover (crimson), potato virus X in, a new host 659
clover (red)
Ascochyta imperfecta from, host range, pathogenicity, and taxonomy 105
bean yellow mosaic virus in
clones resistant to four isolates 323
population necrotic-spotting 633
Fusarium in, mechanism of wilting 631
Leptodiscus terrestris in, host-parasite relations 416, **417, 419**
Meloidogyne arenaria in, population development 631
Meloidogyne hapla in, effect on growth 181
Meloidogyne incognita in, effect on growth 181
root rots in Wisconsin, fungi isolated from 541, **546, 548**
tobacco ringspot virus in, natural occurrence 296
viruses from, formation of local lesions on Gomphrena globosa 636
Cochran, G. W. 82
Cochran, L. C. (701)
coffee, nematodes in, in Guatemala 631
Cohen, Sylvan I. 239
Colberg, C. (69), (865)
Collins, R. P. 632
Collins, Richard J. (627)
Committee on Virus Type Culture Collection 428
Condon, Patricia 267
Converse, Richard H. 527, 570
Cook, A. A. 73, 364, 632
Cook, R. James 632
Cooper, W. E. 632
Corbett, M. K. 346
Corden, Malcolm E. 83, 625
corn
barley stripe mosaic virus in, effect of temperature and host age on disease and seed infection 290, **292**

corn (continued)
Diplodia zeae in
nature of resistance 650
rating index for stalk rot 146, **148**
extracts from healthy plants, antigenic analysis 646
fungi in, factors influencing storage deterioration 703, **705**, **706**
Gibberella roseum in, effect of nitrogen, phosphorus, and potassium 212
Gibberella zeae in, rating index for stalk rot 146, **148**
Pseudomonas andropogoni- in, apparently cause of unreported bacterial stripe 906, **907**, **908**
residues of, effect on soil fungi 22
Trichometasphaeria turcica in, adaptation to resistant and susceptible hosts 261
corn leaf blight, see (under fungus) **Trichometasphaeria turcica**
Cotter, Ralph U. 567
cotton
Alternaria in, cause of chlorosis of seedlings 575
boll rots of, organisms causing at various temperatures 653
Criconemoides ornatum in, effect of resistant and susceptible vars. on population 784
emergence and terminal breakdown, effects of temperature and seed treatment 658
Fusarium in, etiology of wilt 763, **764**
Fusarium oxysporum vasinfectum in, inheritance of resistance as complicated by Meloidogyne incognita acrita 44
Helicotylenchus nannus in, population build-up and pathogenicity 576
Heterodera glycines in, evaluation of rotation and fumigation 635
Hoplolaimus tylenchiformis in
effect of resistant and susceptible vars. on population 784
population build-up and pathogenicity 576
Meloidogyne incognita acrita in
effect of resistant and susceptible vars. on population 784
population build-up and pathogenicity 576
resistance in Upland seedlings 673, **673**, **675**
Meloigodyne incognita incognita in, population build-up and pathogenicity 576
Pratylenchus brachyurus in, effect of resistant and susceptible vars. on population 784
Pythium ultimum in, protection by seed and soil fungicides 643
Rhizoctonia solani in, protection by seed and soil fungicides 643
root-knot nematodes in, effect of resistant and susceptible vars. on populations of 5 spp. 784
Rotylenchulus reniformis in, population build-up and pathogenicity 576
Rotylenchus brachyurus in, population build-up and pathogenicity 576
Trichodorus christiei in, effect of resistant and susceptible vars. on population 784
Couch, Houston B. 319, (532), 761
cowpea
peach yellow bud mosaic virus in, topical susceptibility 659
spotted wilt virus in, topical susceptibility 659
tobacco necrosis virus in, topical susceptibility 659
Craig, Jeweus (868)
crease stem, in tomato, with bunchy top 577
crinkle leaf, in plum, caused by genetic instability 701, **701**, **702**
Crittenden, H. W. (569), 570
Crossan, D. F. 570, (572), (680)
crown rust
in oat, resistance to separated from susceptibility to Helminthosporium victoriae 205, **206**, **208**
in oat, varieties resistant to race 264, 657
crucifers
Alternaria in, species pathogenic to 631
Xanthomonas campestris in, control with antibiotics 642
cucumber
cycloheximide semicarbazone on, bioassay of systemic activity 795
Meloidogyne incognita incognita in, physiological and biochemical studies on galls 650
peach ringspot in, topical susceptibility 659
tobacco necrosis virus in, topical susceptibility 659
yellow bud virus in, topical susceptibility 659
cucurbit wilt, see (under bacteria) **Erwinia tracheiphila**
Cunningham, John L. 632
Cypress
Sclerotium bataticola and Fusarium in, immune to black root rot 653
Stereum in, association with pecky decay 570
Merulius lacrymans in, effects of environment on growth 633
Dahlstrom, R. V. (612)
Daines, R. H. 239
Daines, Robert H. 186, 570
Dallimore, C. E. 83, 83
Daly, J M. (640), (643)
damping-off, see (under castorbean) **Pythium**
Das-Gupta, S. N. 431
Datura stramonium, assay host, for bromegrass mosaic virus 632
Daucus carota, tobacco ringspot virus in, isolated from symptomless host 296
Davey, C. B. (516), 522, (650)
Davidson, Ross W. 570, 633
Davis, B. H. (163), (241)
Davis, D. 841
Davis, James R. (84), (634)
Davis, R. A. 633
dead button, in cherry, nontransmissible disorder, symptoms of 87
Deak, J. (841)
Deese, Dawson C. 633
del Rosario, Maria Salome E. (709)
Desjardins, P. R. (650)
DeVay, J. E. (84), (646), (646)
Diachun, Stephen 323, 633
Dick, J. B. (44)
Dickson, J. G. (1), (434), (439)
Dickson, James G. (403)
Dickson, R. C. (327)
Di Edwardo, A. A. 570, 633
Dieffenbachia, Erwinia chrysanthemi in, associated with bacterial stem rot 696, **697**
Diener, T. O. 161
Diener, Theodor O. 141
Diener, Urban L. 220
Dietz, S. M. (749)
Diller, J. D. 571
Dimitman, J. E. 83, 83
Dimock, A. W. (242)
Dimond, A. E. (240), (329), 634, (634)
Dinoor, A. (562)
Dolliver, J. S. 239
Doolittle, S. P. 7
Downs, R. J. (639)
downy mildew, see (under fungi) **Peronospora parasitica**
Dracaena sanderiana, Aspergillus niger floridanus var. nov. in, cause of stem rot 648
Dropkin, Victor H. 442, 634
Duffus, James E. 389
Durbin, Richard D. (636)
Eckert, J. W. 83, 634, (642)
Edgington, L. V. 239, (625), 634, (634)
Edmunds, L. K. 105
eggplant
Alternaria melongenae in, influence of substrate on spore size 486
black root, see (under eggplant) **Meliolaceae**
Meliolaceae in, morphology and host range 84

eggplant (continued)
Pratylenchus penetrans in, effect on Verticillum wilt incidence 647
Verticillium in, incidence of wilt as affected by Pratylenchus penetrans 647
Ela, Victoria M. 403
Elliott, Edward S. (569)
elm, Sclerotium in, new disease, elm cottony tip blight 240
Elmer, O. H. 744
Endo, R. M. 84
Endo, Robert M. 634
English, H. (84)
English, Harley 84, (550), 634
Epps, James M. 635
Erigeron strigosus, tobacco ringspot ...us in, isolated from symptomless host 296
Erwin, Donald C. (641)
Exconde, Ofelio R. 635
exocortis
in lime, effects on growth, yields, and symptoms 577
in orange, effects on growth, yields, and symptoms 87, 577
Farkas, G. L. 866
Feldmesser, Julius 635
Ferris, J. M. 635
Fezer, Karl D. (910)
Fields, R. W. (287)
fir
dwarf mistletoe on, host specialization in California 650
Merulius lacrymans in, effects of environment on growth 633
Pholiota alnicola and P. squarrosa in, associated with root and butt rots 633
flax
Fusarium oxysporum lini in
extracellular enzyme and toxin production 480
HCN content in relation to resistance 482
flax wilt, see (under flax) **-Fusarium oxysporum lini**
Flock, R. A. 327
Flor, H. H. 223, 603
Foley, D. C. 148
Forbes, I. L. 635
Ford, Charles V. (677)
Fordyce, C. 635
Foster, H. H. 575
Freeman, T. E. 575
French, David W. (659)
Friedman, B. A. 272
Frosheiser, Fred I. 568
fruits, deciduous, viruses in nurseries, importance of virus-free rootstock 240
Fry, P. R. 175
Fuchs, R. J. (83)
fuchsia
Phytophthora parasitica in
cause of root disease 85
influence of temperature 386
Fulkerson, J. F. 377, 394
Fulton, Joseph P. 477
Fulton, N. D. 575
Fulton, Neil D. 541
Fulton, R. W. 635
fungi
Alternaria
in apple, symptoms and species 657
in cotton, cause of chlorosis of seedlings 575
in Cruciferae, species pathogenic to 631
Alternaria citri, irradiation responses, 474
Alternaria melongenae, spore size, influence of substrate 486
Alternaria oleracea
dodine on, uptake and innate toxicity 646
lipid content of conidia, relation to uptake of toxicants 646
two dithiolone derivatives on, high degree of fungitoxicity 650
Alternaria sesami, cultural variants 298, **301**, **302**
fungi (continued)
Alternaria soleni
actinomycetes producing antibiotics against, isolation of 88, **88**
conidial production from filter paper cultures 867
inhibition by filipin 594, **595-598**
lysis of mycelium by natural soil 787
Alternaria tenuis, irradiation responses 476
Aphanomyces euteiches
in pea
introductions with partial resistance 621
soil indexing and effect of rot on yield 287, 287
penetration of roots by zoospores 632
in plant debris, germination of oospores 274, **275**
lysis of mycelium, by natural soil 787
nutrition of, sulphur 637
on media, oospore formation 650
zoospore production, factors affecting 826
Arthrobotrys arthrobotryoides, on root-knot nematodes, tests for control 645
Arthrobotrys conoides, on root-knot nematodes, tests for control 645
Arthrobotrys dactyloides, on root-knot nematodes, tests for control 645
Arthrobotrys musiformis, on Panagrellus redivivus, predacious activity and growth 577
Arthrobotrys oligospora, on Panagrellus redivivus, predacious activity and growth 577
Ascochyta caulicola, in clover, cause of stem disease 643
Ascochyta imperfecta
from alfalfa, host range, pathogenicity, and taxonomy 105
from red clover, host range, pathogenicity, and taxonomy 105
Ascochyta pisi, lysis of mycelium by natural soil 787
Aspergillus, population estimates, soil washing to improve reliability 792
Aspergillus amstelodami, in peanuts, of species frequent in storage 220
Aspergillus candidus, in peanuts, of species frequent in storage 220
Aspergillus chevalieri, in peanuts, of species frequent in storage 220
Aspergillus flavus
in cotton, temperature relation to boll rot 653
inhibition by filipin 594, **595-598**
Aspergillus glaucus, in peanuts, of species frequent in storage 220
Aspergillus niger
dodine on, uptake and innate toxicity 646
fungitoxicity of 8-quinolinol, reversal by amino acids and other chelators 421
in cotton, temperature relation to boll rot 653
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
lipid content of conidia, relation to uptake of toxicants 646
spore germination, effect of mineral nutrition 645
spores
protein synthesis of 656
utilization of $C^{14}H_3COOH$ by 573
sporulation, action of 1,1,1,3,3,3-hexachloro-2-propanol 640
wet and dry spores of, reactions to temperature 85
Aspergillus niger floridanus, var. nov., in Dracaena sanderiana, cause of stem rot 648
Aspergillus repens, in peanuts, of species frequent in storage 220
Aspergillus restrictus, in peanuts, of species frequent in storage 220
Aspergillus ruber, in peanuts, of species frequent in storage 220
Aspergillus tamarii, in peanuts, of species frequent in storage 220

fungi (continued)
Botryosphaeria, in apple, control with lead arsenate 571
Botryosphaeria ribis
fungitoxicity of 8-quinolinol, reversal by amino acids and other chelators 421
in apple
enzymes hydrolyzing cell wall polysaccharides 258
physiological factors affecting susceptibility 91
relation to rot 394, **397**
Botrytis
in onion, cause of blast 76, **76, 77**
nystatin on, toxicity to spores 163
Botrytis allii
in onion
influence of growing, curing, and storage 87
most common of Botrytis spp. causing blast 76, **76, 77**
irradiation responses 474
Botrytis cinerea
inhibition by antibiotic produced by Pullularia pullulans 82
irradiation responses
in strawberry
influence of fungicides on 657
initiation of fruit rot 491, **492, 493**
in tomato, incidence changes from liming the soil 655
lysis of mycelium by natural soil 787
sporulation, action of 1,1,1,3,3,3-hexachloro-2-propanol 640
wet and dry spores of, reactions to temperature 85
Botrytis gladiolorum, asexual reproduction, vitamin nutrition in relation to 241
Candida albicans
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
Catenaria, in nematodes, virulent to several different genera 629
Cephalosporium, in alfalfa, associated with root rot 241
Ceratocystis fagacearum
in apple, susceptibility of several varieties 177
in Chinese oak, effect of temperature and moisture on wilt 640
in oak in North Carolina, distribution in roots 775
lysis of mycelium by natural soil 787
with Hypoxylon punctulatum, nutritional competition 573
Ceratocystis fimbriata
in carrot, fungitoxic compound isolated from tissue 267
in potato, changes in host proteins 655
perithecia, effects of nitrogen and calcium on formation 631
Ceratocystis fimbriata planti, esters produced by 632
Ceratostomella fimbriata
in sweet potato, metabolic alterations induced 30
in vitro, selective effect of Pimaricine on 638
Cercospora antirrhini, in snapdragon, cause of stunting and defoliation 190, **191**
Cercospora apii, in celery, inoculum production and seedling evaluation 605
Cercospora capsici, in pepper, effect of fertilization 577
Cercospora kikuchii
in basal liquid medium, effect of amino acids and sugars on growth 569
in soybean, control on seed 570
Cercospora musae, in banana, control with oil sprays timed to disease cycle 488, **490**
Cercospora sojina, inhibition by filipin 594, **595-598**
Cladosporium
in peanuts, of species frequent in storage 220
irradiation responses 474
Cladosporium cucumerinum
acetic acid on, toxicity of 781
growth, effect of temperature, pH, and nutrients 583
lysis of mycelium by natural soil 787
Cladosporium fulvium, in tomato, resistance of varieties 637
fungi (continued)
Cladosporium herbarum, wet and dry spores of, reactions to temperature 85
Cochliobolus carbonum, genetics of compatibility in 158
Cochliobolus victoriae, perfect stage of Helminthosporium victoriae 774
Colletotrichum, enzyme production, pectinolytic and cellulolytic 659
Colletotrichum capsici
oxygen uptake, effect of maneb in presence of substrates found in oxidative pathways 572
oxygen use and amino acid and sugar content, effect of copper and glyodin fungicides 680
Colletotrichum circinans, lysis of mycelium by natural soil 787
Colletotrichum fragariae, in strawberry, associated with summer killing 575
Colletotrichum fuscum, colletotin, a toxin produced by 325, **326**
Colletotrichum gloeosporioides, in vitro, selective effect of Pimaricine on 638
Colletotrichum lagenarium
enzyme production, pectinolytic and cellulolytic 659
for bicassay of systemic activity of cycloheximide semicarbazone in cucumber 795
Colletotrichum lini, inhibition by antibiotic produced by Pullularia pullulans 82
Colletotrichum phomoides
inhibition by filipin 594, **595-598**
lysis of mycelium by natural soil 787
Colletotrichum pisi, lysis of mycelium by natural soil 787
Colletotrichum truncatum, in lima bean, resistance in P.I.199791 and 186984 573
Corynespora, in sesame, species pathogenic appeared identical to C. cassiicola 263, **265**
Cronartium fusiforme, in pine, inoculation techniques 48, **49, 50**
Cornartium ribicola
germination of sporidia, effect of environment 61, **63, 64, 67**
in pine (white), inoculations in mist chambers 657
Cylindrocarpon radicicola, in lily, antagonism and synergism with other organisms 615, **616, 618**
Cytospora, canker in stone fruit trees, occurrence in California 84
Cytospora leucostoma, occurrence in canker of stone fruit trees, tentative identification 84
Cytospora rubescens
in stone fruits, pathogenic variation of isolates 86
inhibition by antibiotic produced by Pullularia pullulans 82
occurrence in canker of stone fruit trees, tentative identification 84
Dactylaria brochopaga, on root-knot nematodes, tests for control 645
Dactylaria thaumasia
on Panagrellus redivivus, predacious activity and growth 577
on root-knot nematodes, tests for control 645
Dactylella, on Panagrellus redivivus, predacious activity and growth 577
Dactylella ellipsospora
on Panagrellus redivivus, predacious activity and growth 577
on root-knot nematodes, tests for control 645
Diaporthe batatatis, in sweet potato, effect of bed temperature and seed dip on incidence of sprout decay 186
Diaporthe phaseolorum sojae
in basal liquid medium, effect of amino acids and sugars on growth 569
in soybean, control on seed 570
Diplocarpon rosae
in rose
control with fungicide-acaricide combination 573
leaflet assay of susceptibility 572

fungi (continued)
Diplodia natalensis, irradiation responses 474
Diplodia theobromae, in vitro, selectve effect of Pimaricine on 638
Diplodia tubericola, nystatin on, toxicity to spores 163
Diplodia zeae
in corn
nature of resistance 650
rating index for stalk rot 146, **148**
inhibition by filipin 594, **595-598**
Erysiphe cichoracearum
in lettuce
effects of temperature and moisture stress 304
relation of microclimates 450
Erysiphe graminis, in wheat, inhibition by antibiotic produced by Streptomyces sp. 841
Erysiphe graminis hordei
in barley
genotypes of host and pathogen 736
inheritance of 5 genes conditioning pathogenicity 647
Erysiphe graminis tritici, in wheat, genetic control of host-parasite relations 454
Erysiphe polygoni, in bean, inhibition by antibiotic produced by Streptomyces sp. 841
Exidia recisa, inhibition by filipin 594, **595-598**
Fomes annosus, inhibition by filipin 594, **595-598**
Fusarium
association with seedling blight of smooth bromegrass 1
in banana, physical barriers in relation to resistance 628
in clover (red), mechanism of wilting 631
in cotton, etiology of wilt 763, **764**
in tomato, mechanics of water transport in 634
in 23 tree species, susceptibility to black root rot 653
in vitro, selective effect of Pimaricine on 638
population estimates, soil washing to improve reliability 792
Streptomyces on, effect in culture 631
Trichoderma on, effect in culture 631
Fusarium cubense
in banana, role of pectic enzymes in resistance 633
in tomato, role of pectic enzymes in resistance 633
Fusarium lycopersici
in banana, role of pectic enzymes in resistance 633
in tomato, role of pectic enzymes in resistance 633
inhibition by tetrin, antibiotic produced by Streptomyces 817
Fusarium moniliforme
in cotton, temperature relation to boll rot 653
in red clover, in root rots in Wisconsin 541, **546, 548**
inhibition by filipin 594, **595-598**
Fusarium oxysporum
for bioassay of systemic activity of cycloheximide semicarbazone in cucumber 795
in lemon, relation to Radopholus similis in roots 635
in lily, antagonism and synergism with other organisms 615, **616, 618**
in marigold, isolate causing wilt of 85
in red clover, in root rots in Wisconsin 541, **546, 548**
in tomato, a calcium requirement for growth-regulator-induced resistance 625, **626**
inhibition by filipin 594, **595-598**
Fusarium oxysporum cubense
nabam activity against 83
physiology of an isolate 607
Fusarium oxysporum conglutinans
in cabbage
oxidative enzymes in host 370
proteins in host 198, **201, 202**
in radish, resistance 807, **811, 813**
production of pectolytic enzymes and fusaric acid by, in relation to cabbage yellows 367
Fusarium oxysporum dianthi
in carnation
disease control by culture-indexing 356, **358**
influence of nitrogen and potassium nutrition 636
fungi (continued)
Fusarium oxysporum gladioli, in gladiolus, resistance of 211 varieties and 3 species 572
Fusarium oxysporum lini
extracellular enzyme and toxin production 480
in flax, HCN content in relation to resistance 482
Fusarium oxysporum lycopersici
actinomycetes producing antibiotics against isolation of 88, **88**
in tomato, respiratory responses to 192
pathogenesis, role of cellulolytic enzymes 329
Fusarium oxysporum sedi, n.f. 651
Fusarium oxysporum vasinfectum, in cotton, inheritance of resistance as complicated by Meloidogyne incognita acrita 44
Fusarium roseum, in red clover, in root rots in Wisconsin 541, **546, 548**
Fusarium roseum cerealis
antagonists among soil fungi 658
in carnation, histochemical and morphological studies 651
Fusarium solani
26 chemicals on, concentration for inhibition 870
in lemon, relation to Radopholus similis in roots 635
in red clover in root rots in Wisconsin 541, **546, 548**
mono- and dialkyl-substituted dithiocarbamates on comparative toxicity 641
Fusarium solani phaseoli
pathogenesis of, effect of nitrogen sources and glucose 137, **138, 139**
saprophytic survival in soil, physiology of 56
Fusarium solani pisi
in pea
commercial varieties tested for reaction 637
soil indexing and effect of rot on yield 287, **287**
lysis of mycelium, by natural soil 787
Fusicladium effusum
in pecan
physiologic specialization 527
protectant fungicides 574
Geotrichum candidum
in muskmelon, susceptible to most isolates tested 665, **667, 668, 671**
in peach, susceptible to most isolates tested 665, **667, 668, 671**
in tomato, strains from various sources 665, **667, 668, 671**
in watermelon, susceptible to most isolates tested 665, **667, 668, 671**
pathogenicity and taxonomy 665, **667, 668, 671**
Gibberella fujikuroi
in corn, cross-inoculations with G. zeae 239
in tomato, cross-inoculations with G. zeae 239
Gibberella roseum, in corn, effect of nitrogen phosphorus, and potassium 212
Gibberella roseum cerealis, effect of crops and crop residues on 22
Gibberella zeae
in corn
cross-inoculations with G. fujikuroi 239
rating index for stalk rot 146, **148**
in tomato, cross-inoculations with G. fujikuroi 239
inhibition by filipin 594, **595-598**
lysis of mycelium by natural soil 787
Gilbertella persicaria, spores, effect of alcohols 790
Gliocladium roseum, in red clover, in root rots in Wisconsin 541, **546, 548**
Gloeodes pomigena, isolates from apple, morphological and nutritional differences 571
Gloeosporium, irradiation responses 474
Gloeosporium musarum, irradiation responses 474
Glomerella cingulata
actinomycetes producing antibiotics against isolation of 88, **88**
dodine on, uptake and innate toxicity 646
fungistasis by soils, direct observation of 644

fungi, Glomerella cingulata (continued)
in apple, physiological actors affecting susceptibility 91
in thiram solution, resulting degradation of thiram 651
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
lipid content of conidia, relation to uptake of toxicants 646
lysis of mycelium by natural soil 787
physiologic responses to various media and growth substances 86
spores
protein synthesis of 656
utilization of $C^{14}H_3COOH$ by 573
Glomerella lagenaria, enzyme production, pectinolytic and cellulolytic 659
Gnomonia veneta, in sycamore, early stage of anthracnose 648
Guignardia bidwellii, in culture and field, growth and sporulation 630
Hansenula subpelliculosa, inhibition by filipin 594, **595-598**
Helminthosporium
conidial morphology, relation to interspecific fertility 649
interspecific crosses 375
Helminthosporium avenae
in cereals, morphology, physiology, and pathology 688
in forage grasses, morphology, physiology, and pathology 688
Helminthosporium bromi
in cereals, morphology, physiology, and pathology 688
in forage grasses, morphology, physiology, and pathology 688
Helminthosporium carbonum
crosses with H. victoriae, inheritance of pathogenicity and mating type 649
inhibition by filipin 594, **595-598**
Helminthosporium dictyoides
in forage grasses, morphology, physiology, and pathology 691, **693**
isolate from meadow and tall fescues, physiologic form name proposed, H. dictyoides f. sp. dictyoides n.f. 697, **693**
isolate from perennial and annual ryegrasses, physiologic form name proposed, H. dictyoides f. sp. perenne n.f. 691, **693**
Helminthosporium gramineum
in cereals, morphology, physiology, and pathology 688
in forage grasses, morphology, physiology, and pathology 688
Helminthosporium oryzae
in rice, relation of nitrogen to disease 434, **437**
induced mutation and cytology 439, **440, 441**
Helminthosporium phaeocomes
in cereals, morphology, physiology, and pathology 688
in forage grasses, morphology, physiology, and pathology 688
Helminthosporium sativum
association with seedling blight of smooth bromegrass I
in barley, evaluating resistance by lesion type 632
in oat, pathogenic specialization 627
in rye, seed treatment 576
in soil, effect of nutrition on conidia germination 629
in sorghum, pathogenic specialization 627
in wheat, pathogenic specialization 627
lysis of mycelium by natural soil 787
pathogenic specialization 627
spores of, soil infestation method for studying 860, **861**
Helminthosporium teres
in cereals, morphology, physiology, and pathology 688
in forage grasses, morphology, physiology, and pathology 688
Helminthosporium turcicum, physiologic specialization 217
Helminthosporium vagans
conidial production from filter-paper cultures 867

fungi Helminthosporium vagans (continued)
sporulation, action of 1,1,1,3,3,3-hexachloro-2-propanol 640
Helminthosporium victoriae
actinomycetes producing antibiotics against isolation of 88, **88**
disease of, transmission 644
diseased, reduction in pathogenicity and toxin production 457, **458**
crosses with H. carbonum, inheritance of pathogenicity and mating type 649
in oats, susceptibility to, separated from resistance to crown rust 205, **206, 208**
isolation of victoxinine 324
on synthetic media, toxin production with different nitrogen sources 629
perfect stage of Cochliobolus victoriae 774
spore germination, effect of mineral nutrition 645
toxin production, on synthetic media containing different nitrogen sources 629
Hypoxylon pruinatum, ascospore germination and colony development, effect of bacteria in the perithecia 659
Hypoxylon punctulatum, with Ceratocystis fagacearum, nutritional competition 573
in corn, factors influencing storage deterioration, 703, **705, 706**
Isariopsis, in magnolia, associated with new leaf spot 637
Lenzites trabea, inhibition by filipin 594, **595-598**
Leptodiscus terrestris
in alfalfa, host-parasite relations 416, **417, 419**
in birdsfoot trefoil, host-parasite relations 416, **417, 419**
in red clover, host-parasite relations 416, **417, 419**
Lophodermium, in pine, symptoms 628
Macrophomina phaseoli, sclerotia, thermal death range 628
Melampsora lini
asexual variants 223
urediospore culture, inheritance of induced mutation to virulence 603
Meliolaceae, member in potato and egg plant 84
Merulius lacrymans, in 13 tree species, effects of environment on growth 633
Microsporum canis, inhibition by tetrin, antibiotic produced by Streptomyces 817
Monascus purpureus, inhibition by filipin 594, **595-598**
Monilinia fructicola
n-dodecylguanidine acetate on, mechanisms of fungitoxic action 830
inhibition by filipin 594, **595-598**
irradiation responses 474
lipid content of conidia, relation to uptake of toxicants 646
lysis of mycelium by natural soil 787
nystatin on, toxicity to spores 163
sporulation, action of 1,1,1,3,3,3-hexachloro-2-propanol 640
two dithiolane derivatives on, high degree of fungitoxicity 650
Mortierella pusilla, Piptocephalis virginiana on, nutrient effect on parasitism by 655
Mucor, wet and dry spores of, reactions to temperature 85
Mucor hiemalis, inhibition, by filipin 594, **595-598**
Mucor ramannianus, 26 chemicals on, concentration for inhibition 870
Mycoderma cereviseae, inhibition by tetrin, antibiotic produced by Streptomyces 817
Mycosphaerella davisii, in clover, cause of stem disease 643
Mycosphaerella lethalis, in clover, cause of stem disease 643
Mycosphaerella musicola
in banana
fungistasis by petroleum oil 865
precision spray technique for evaluating control with oils 69, **71**
Neofabraea malicorticis, in apple, physiological factors affecting susceptibility 91

fungi (continued)
Neurospora crassa, spore germination, effect of mineral nutrition 645
Neurospora sitophila
dodine on, uptake and innate toxicity 646
functional enzymes in conidia, interaction of captan and dichlone with 649
lipid content of conidia, relation to uptake of toxicants 646
spores, utilization of $C^{14}H_3COOH$ by 573
Nigrospora oryzae, in cotton, temperature relation to boll rot 653
Ovulinia azaleae, in azalea, control with thiram 576
Pellicularia filamentosa, single-basidiospore isolates, effect of substrate on virulence 282, **284**, **285**
Pellicularia rolfsii, irradiation responses 474
Penicillium
inhibition by antibiotic produced by Pullularia pullulans 82
Piptocephalis xenophila on, nutrient effect on parasitism by 655
population estimates, soil washing to improve reliability 792
sporulation, action of 1,1,1,3,3,3-hexachloro-2-propanol 640
Penicillium chrysogenum, inhibitor by filipin 594, **595-598**
Penicillium citrinum, in peanuts, of species frequent in storage 220
Penicillium digitatum
in citrus
control with dichloroisocyanuric acid 83
ammonia-generating formulations for control 634
effects of volatile fungicides in packages 855
irradiation responses 474
wet and dry spores of, reactions to temperature 85
Penicillium expansum
irradiation responses 474
wet and dry spores of, reactions to temperature 85
Penicillium funiculosum
in peach, strain causing a wilt disease 161, **161**
in peanuts, of species frequent in storage 220
in pear, strain causing a wilt disease 161, **161**
Penicillium italicum
in oranges, effects of volatile fungicides in packages 855
irradiation responses 476
wet and dry spores of, reactions to temperature 85
Penicillium oxalicum
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
Peridermium harknessii, in pine, development of western gall rust 876, **877**, **878**
Peronospora parasitica
in broccoli
inheritance of resistance 241
role of oospores in downy mildew 93, **94**
in cabbage, role of oospores in downy mildew 93, **94**
Pestalotia, in vitro, selective effect of Pimaricine on 638
Pholiota alnicola, in fir and spruce, associated with root and butt rots 633
Pholiota squarrosa, in fir and spruce, associated with root and butt rots 633
Phoma, irradiation responses 474
Phoma herbarum medicaginis, in alfalfa, effect of temperature on black stem 628
Phomopsis citri, irradiation responses 474
Phomopsis juniperovora, in eastern redcedar, survival in the nursery 639
Phycomyces nitens, inhibition by filipin 594, **595-598**
Physalospora obtusa
in apple, physiological factors affecting susceptibility 91
inhibition by antibiotic produced by Pullularia pullulans 82
Phytomonas marginata, in gladiolus, association with primary pathogen of basal leaf and stem spotting 648

fungi (continued)
Phytophthora
in citrus, separating isolates pathogenic to 83
inter- and intraspecific pairings in, production of oospores by 653
Phytophthora cactorum, 26 chemicals on, concentration for inhibition 870
Phytophthora capsici, in pepper, resistance in 613 lines, varieties, or plant introductions 642
Phytophthora cinnamomi
in avocado
attraction of zoosores by roots 660
methods of isolation 87
soil fungicides for prevention and therapy 660
in pear, possible cause of quick collapse 630
mono- and dialkyl-substituted dithiocarbamates on comparative toxicity 641
Phytophthora citrophthora
in citrus, girdling to reduce size of gummosis lesions 83
in soil, estimation of disease potential 717, **718**
Phytophthora cryptogea, sporangia, factors affecting formation of 641
Phytophthora drechsleri, in safflower, development of resistant varieties 129, **129**
Phytophthora infestans
in potato
nature of partial resistance of 3 species 637
scopolin produced in host 398
irradiation responses 474
oospores of, problems of germination 573
sexuality in 123, **124**, **125**
Phytophthora megasperma sojae, in lupine, cause of root and stem rot 641
Phytophthora palmivora, in vitro, selective effect of Pimaricine on 638
Phytophthora parasitica
in citrus, girdling to reduce size of gummosis lesions 83
in fuchsia
cause of root disease 85
influence of temperature 386
in soil, estimation of disease potential 717, **718**
in tobacco, effect of Meloidogyne on black shank 899, **901**, **903**, **905**
Phytophthora phaseoli, in lima bean, aids for forecasting 572
Phytophthora sojae, culture and storage, frozen-lima-bean agar for 136
Piptocephalis virginiana, on Mortierella pusilla, nutrient effect on parasitism by 655
Piptocephalis xenophila, on Penicillium, nutrient effect on parasitism by 655
Pleiochaeta setosa, in white lupine, seed treatment 577
Pleospora phaeocomes, Helminthosporium stage, in cereals and forage grasses 688
Podosphaera leucotricha, in apple, biochemical response of host 844
Poria incrassata, in pine, spread through soil to 571
Pseudoperonospora humuli, in hops, effect on streptomycin absorption and mildew development 278, **278**
Pseudopeziza medicaginis, in alfalfa, screening for resistance 568
Puccinia antirrhini, in snapdragon, effect of temperature on fungitoxicant action 242
Puccinia asparagi, sphere in water mounts, probably nucleus 85
Puccinia carthami, diploid nucleus in unstained water mounts 85
Puccinia coronata, urediospores, factors affecting germinability 639
Puccinia coronata avenae
in barley, induced susceptibility to 630
in oats
host-parasite interactions of race 202 in 8 vars. 914, **915**, **917**
inheritance of resistance of C.I. 7232, a derived tetraploid 779

fungi Puccinia coronata avenae (continued)
inhibition by antibiotic produced by Streptomyces sp. 841
in Rhamnus palaestina, effect of host on origin and persistence 562
in wheat, induced susceptibility to 630
Puccinia graminis
fertilization of pycnia with urediospores and aeciospores 567
sphere in water mounts, probably nucleus 85
Puccinia graminis avenae
in barley, induced susceptibility to 630
in oat, altering effect of resistance genes 630
in wheat, induced susceptibility to 630
Puccinia graminis tritici, fertilization, pycnia with urediospores 636
in wheat
development in leaves treated with sugars and sugar alcohols 114, **116**
effect of $NiCl_2$ on plant development 640
half-life of representative systemic chemicals 627
inhibition by antibiotic produced by Streptomyces sp. 841
metabolic changes in host 636
nature and turnover of organic acids in 643
predisposition of seedlings 339, **339**
relations between inoculum density and infection 86
survival of races near barberry 40
several of urediospores on dry foliage 400
toxin extracted from 130, **131, 133**
new races, production by tissue transplants 636
pathogenicity in, mutation for 653
spores, utilization of $C^{14}H_3COOH$ by 573
urediospore movement, upper Mississippi River Valley 535, **536**
Puccinia helianthi, spores, utilization of $C^{14}H_3COOH$ by 573
Puccinia malvacearum, sphere in water mounts, probably nucleus 85
Puccinia menthae, in mint, control with nickel salts 866
Puccinia rubigo-vera, in wheat, inhibition by antibiotic produced by Streptomyces sp. 841
Pullularia pullulans, antibiotic produced by, activity of 82
Pythium
association with seedling blight of smooth bromegrass 1
in castorbean, relations of variety, temperature, and seed immaturity to pre-emergence damping-off 473
lysis of mycelium by natural soil 787
Pythium aphanidermatum
in ryegrass, effects of temperature 575
lysis of mycelium by natural soil 787
mono- and dialkyl-substituted dithiocarbamates on, comparative toxicity 641
Pythium debaryanum
26 chemicals on, concentration for inhibition 870
inhibition by filipin 594, **595-598**
irradiation responses 474
Pythium ultimum
effect of crops and crop residues on 22
for bioassay of systemic activity of cycloheximide semicarbazone in cucumber 795
in cotton, protection by seed and soil fungicides 643
in sugar beet, protection by seed and soil fungicides 643
Rhizoctonia
in red clover in root rots in Wisconsin 541, **546, 548**
in soil, saprophytic activity and survival 650
inhibition by filipin 594, **595-598**
Rhizoctonia fruit rot, of tomato, control tests in laboratory, greenhouse, and field 570
Rhizoctonia solani
association with seedling blight of smooth bromegrass 1
26 chemicals on, concentration for inhibition 870
for bioassay of systemic activity of cycloheximide semicarbazone in cucumber 795
in bean, effects of decomposing green plant materials and associated microfloras 516, **518**
in cotton, protection by seed and soil fungicides 643
in Seaside bentgrass, effect of nutrition, pH, and soil moisture 532
in soil, effect of dry mature plant materials and nitrogen 522
sugar beet, protection by seed and soil fungicides 643
lysis of mycelium by natural soil 787
mono- and dialkyl-substituted dithiocarbamates on, comparative toxicity 641
radioisotopes in, movement 646
Rhizopus, nystatin on, toxicity to spores 163
Rhizopus arrhizus
in almond
fumaric acid determination 646
role of fumaric acid in hull rot 646
Rhizopus circinans
in almond
fumaric acid determination 646
role of fumaric acid in hull rot 646
Rhizopus nigricans
in cotton, temperature relation to boll rot 653
irradiation responses 474
Rhizopus stolonifer
26 chemicals on, concentration for inhibition 870
in almond
fumaric acid determination 646
role of fumaric acid in hull rot 646
in peach, effect of postharvest temperature and moisture 558
spores, effect of alcohols 790
wet and dry spores of, reactions to temperature 85
Rhynchosporium secalis
mutants induced by ultraviolet irradiation 642
in barley, variations in pathogenicity 642
Russula, 26 chemicals on, concentration for inhibition 870
Saccharomyces cerevisiae
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
Saccharomyces globosus
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
Saccharomyces pastorianus
enzymes in, effect of dodine 569
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
n-dodecylguanidine acetate on mechanisms of fungitoxic action 830
Schizophyllum commune, inhibition by filipin 594, **595-598**
Sclerotinia fructicola
in Prunus, effect of sodium pentachlorophenoxide and lime-sulfur 649
inhibition by antibiotic produced by Pullularia pullulans 82
spores, effect of alcohols 790
wet and dry spores of, reactions to temperature 85
Sclerotinia homeocarpa, in Kentucky bluegrass, effect of nutrition, pH, and soil moisture 761
Sclerotinia laxa
in Prunus, effect of sodium pentachlorophenoxide and lime-sulfur 649
inhibition by antibiotic produced by Pullularia pullulans 82
relative pathogenicity with S. fructicola, on almond, apricot, nectarine, prune, and peach, 550, **556**
wet and dry spores of, reactions to temperature 85
Sclerotinia sclerotiorum
in gloxinia, new blight disease 638
irradiation responses 476
lysis of mycelium by natural soil 787

fungi Sclerotinia sclerotiorum (continued)
mono- and dialkyl-substituted dithiocarbamates on, comparative toxicity 641
Sclerotium, in elm, new disease, elm cottony tip blight 240
Sclerotium bataticola, in 23 tree species, susceptibility to black root rot 653
Sclerotium rolfsii
in peanut, comparative rot development in 2 varieties 575
in tomato, control with chemicals and crop rotation 577
mono- and dialkyl-substituted dithiocarbamates on, comparative toxicity 641
Septoria passerinii, in barley, role of straw in epiphytology 910, **911**
Septoria tritici
in wheat, tests for resistance 654
in winter wheat, losses from 630
Sphaceloth'eca reiliana
in soil, method of chlamydospore germination 627
in sorghum, races of 627
Sphacelotheca sorghi, in Kansas aeromycology 332
Stemphylium
leguminicolous and related species, pathogenicity and morphology 757, **758, 759**
spore germination, effect of mineral nutrition 645
Stemphylium radicina, irradiation responses 474
Stemphylium sarcinaeforme
inhibition by filipin 594, **595-598**
lipid content of conidia, relation to uptake of toxicants 646
lysis of mycelium by natural soil 787
sporulation, action of 1,1,1,3,3,3-hexachloro-2-propanol 640
Stemphylium solani, inhibition by filipin 594, **595-598**
Stereum, in cypress, association with pecky decay 570
Streptomyces
antibiotic produced by, inhibition of wheat leaf rust, wheat stem rust, crown rust of oats, and powdery mildew of bean and wheat 841
26 chemicals on, concentration for inhibition 870
isolation from soil, superior media for 644
on Fusarium, effect in culture 631
tetrin, new antifungal antibiotic produced by 817
Streptomyces griseus, antifungal antibiotic produced by strain, partial purification and biological activity 169, **171**
Streptomyces ipomoea
in sweet potato
evaluating lines 574
methods determining reaction of lines to 822, **823-825**
Thielaviopsis, esters produced by 632
Thielaviopsis basicola
26 chemicals on, concentration for inhibition 870
in bean, influence of pH on root rot 628
in citrus
pathogenicity and isolation from field roots 86
effect of temperature on pathogenesis 657
in culture, influence of pH on growth 628
in forage legumes, technique of determining seedling reaction 638
in poinsettia, influence of pH on root rot 628
Tilletia caries
a solopathogenic line 641
compatibility with T. contraversa 641
in wheat
seed treatment, fungicide vapor action ineffective 581
effect of postinfection environment 651
pathogenic races, differential longevity of teliospores 51
Tilletia contraversa, compatibility with T. caries 641
Tilletia foetida, pathogenic races, differential longevity of teliospores 51
Torula, inhibition by tetrin, antibiotic produced by Streptomyces 817
Torula sacchari, in peanuts, of species frequent in storage 220
fungi (continued)
Torulopsis utilis, inhibition by filipin 594, **595-598**
Trichoderma, on Fusarium, effect in culture 631
Trichoderma viride
26 chemicals on, concentration for inhibition 870
inhibition by filipin 594, **595-598**
Trichometasphaeria turcica, in corn, adaptation to resistant and susceptible hosts 261
Trichophyton interdigitale
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
Tylenchorhynchus
in peach, preplant control 575
swarming mechanism 639
morphological variation 571
Uromyces phaseoli
spores
protein synthesis of 656
utilization of $C^{14}H_3COOH$ by 573
uredospore production 659
Uromyces phaseoli typica
in bean, nature and turnover of organic acids in 643
uredospores, self-inhibitors of germination from 629
Ustilago avenae
haploid lethal factors, in association with U. kolleri 749, **750**
interracial hybrids involving 7 races, inheritance of pathogenicity 766
Ustilago hordei
in Kansas aeromycology 332
wet and dry spores of, reactions to temperature 85
Ustilago kolleri, haploid lethal factors, in association with U. avenae 749, **750**
Ustilago maydis
in Kansas aeromycology 332
spores
protein synthesis of 656
utilization of $C^{14}H_3COOH$ by 573
Ustilago nuda, in barley, detecting viable mycelium after seed treatments 647
Ustilago tritici, in wheat, root and shoot development 645
Venturia inaequalis
dodine on, uptake and innate toxicity 646
in apple, biochemical response of host 844
in vitro, growth and metabolism of phloridzin and other host compounds by 639
Verticillium
in egg plant, incidence of wilt as affected by Pratylenchus penetrans 647
inhibition
by filipin 594, **595-598**
by tetrin, antibiotic produced by Streptomyces 817
Verticillium albo-atrum
actinomycetes producing antibiotics against, isolation of 88, **88**
in castorbean, symptoms of wilt 85
in mint, determining levels of resistance 569
in potato
amount in Idaho certified seed 84
relation of plant age to infection 86
role of pectic enzymes in resistance 633
in soil, survival in muck 637
in tomato, role of pectic enzymes in resistance 633
inhibition by antibiotic produced by Pullularia pullulans 82
lysis of mycelium by natural soil 787
mono- and dialkyl-substituted dithiocarbamates on, comparative toxicity 641
Verticillium albo-atrum menthae, host specificity 635
Verticillium dahliae, in popular (yellow), symptoms 572
Zygorhynchus moelleri, inhibition by filipin 594, **595-598**
Zygosaccharomyces prioranus
inhibition
by filipin 594, **595-598**

fungi Zygosaccharomyces prioranus (continued)
by tetrin, antibiotic produced by Streptomyces 817
fusiform rust, see (under fungi) **Cronartium fusiforme**
Futrell, Maurice C. (629)
Galindo A., J. 123
Gallegly, M. E. (123), (573), (574), (653)
Garber, J. D. (841)
Garber, M. J. (855)
Garber, R. H. (643)
gardenia, Meloidogyne incognita acrita, M. incognita incognita, and M. hapla in, effects 633
Gardner, Wayne S. (86)
Garren, Kenneth H. 575
Garrett, W. N. 636, 636
Gasiorkiewics, E. C. 636, 636
geranium, viruses in, mechanical transmission and host range 652
Gerdemann, J. W. (416)
Gerwitz, David L. 636
Giamalva, Mike J. 575
Gilmer, R. M. 240, 624, 636
Gilpatrick, J. D. (87), (660)
gladiolus
basal leaf and stem spotting, two bacteria commonly isolated 648
Fusarium oxysporum gladioli, resistance of 211 varieties and 3 species 572
Meloidogyne incognita acrita in, influence of preplanting and row treatments 574
Phytomonas marginata in, association with primary pathogen of basal leaf and stem spotting 648
Goheen, A. C. (308)
Gold, A. Herbert 84
Goldberg, Herbert S. (851)
Gomphrena globosa
viruses from red clover in, production of local lesions 636
Goodchild, D. J. (497)
Goodman, Robert N. 325, 851
Gordon, C. C. 84
Goth, R. W. 636
Gottlieb, David 594, 817
Govindu, H. C. (884)
Graham, J. H. 637, (691), 757
Graham, S. O. (86)
Graham, T. W. 575
grains (small), sensitive to atmospheric ozone 639
Grant, B. R. 637
Graves, Clinton H., Jr. 576
graywall
in tomato
distinguished from internal browning 648
incidence and sources of resistance 408
grapefruit
Belonolaimus longicaudatus in, effects on roots 152, **154**
Trichodorus christiei in, effects on roots 152, **154**
grasses
bromegrass, Helminthosporium gramineum group in, morphology, physiology, and pathology 688
forage
Pleospora phaeocomes in ,Helminthosporium stage of 688
Helminthosporium avenae in, morphology, physiology, and pathology 688
Helminthosporium bromi in, morphology, physiology, and pathology 688
Helminthosporium dictyoides in, morphology, physiology, and pathology 691, **693**
Helminthosporium gramineum in, morphology, physiology, and pathology 688
Helminthosporium phaeocomes in, morphology, physiology, and pathology 688
Helminthosporium teres in, morphology, physiology, and pathology 688
Kentucky bluegrass, Sclerotinia homeocarpa in, effect of nutrition, pH, and soil moisture 761
orchardgrass, Helminthosporium gramineum group in, morphology, physiology, and pathology 688
grasses (continued)
tall oatgrass, Helminthosporium gramineum group in, morphology, physiology, and pathology 688
Green, H. J. (639)
Green, R. J. (635)
Green, Ralph J., Jr. 637
greenbugs, see **Toxoptera graminum**
Gregory, Garold F. (645)
Grimm, G. R. (635)
Grindeland, R. 779
Grogan, R. G. (175), (642)
Guthrie, James W. 84
Guzmán N., Julia 637
Haasis, F. A. 637
Hadden, S. J. (209), (576)
Haenseler, C. M. (239)
Hagedorn, D. J. (632), 637
Haglund, W. A. 637
Halisky, P. M. (653), (766)
Hall, Dennis H. (278)
Halmos, S. (628), (841)
Halperin, J. (562)
Hamilton, R. I. (635), 638
Hansen, A. Juergen 638
Hansing, Earl D. (635), (645)
Hanson, E. W. (105), (631), (643)
Hanson, Earle W. (541)
Hare, W. W. 638
Harpaz, I. (100)
Harrison, Martin B. 638, (659)
Hart, Helen (645)
Hartwell, W. V. 612
Hasbrouck, E. R. 571
head smut, see (under sorghum) **Sphacelotheca reiliana**
Hebert, T. T. (649)
Heidrick, Lee E. (637)
Heitefuss, R. 198, 367, 370
Heliconia, Pseudomonas solanacearum in, relation to bacterial wilt of banana 660, **662, 663**
hemlock
canker, associated with poor soil drainage 569
Merulius lacrymans in, effects of environment on growth 633
Hendrix, Floyd F., Jr. 638
Henneberry, T. J. (572), (573)
Henson, L. 638
Henson, Lawrence (323), (633)
Hernandez, Teme P. (575)
Herridge, E. Anne 84
Heuberger, J. W. (258), 571
Hibbertia scandens, virus disease of 634
Hickey, K. D. 571
Hildebrand, E. M. 571, 571, 751
Hildebrandt, A. C. (587), (652)
Hill, A. C. 639
Hills, F. J. 639, 639
Himelick, E. B. (648)
Hirai, Tokuzo (344)
Hissong, G. (711)
Hobbs, E. LaGrande 639
Hodges, C. S. (637), 639
Hollis, J. P. 639, 639
holly, leaf spot, associated with copper fungicides 84
Holowczak, J. 640
Holmes, F. O. 240
Holmes, F. W. 240
Holmes, Francis O. 572, 777
Holton, C. S. (51), (581), (641), 749, 766
Honma, S. (605)
Hood, J. R. (650)
Hooker, W. J. (231), (629)
hops
hop mosaic in, mild strain of 655
Pseudoperonospora humuli in, effect on streptomycin absorption and mildew development 278, **278**

Hops (continued)
streptomycin in, absorption, translocation, and retention 351
Horn, N. L. (575), (658)
Horsfall, James G. (421), 640
Houston, Byron R. (85)
Houston, D. R. 640
Hughes, J. C. 398
Husain, Akhtar 329
Hutchinson, M. T. 308
Hyre, R. A. 572
internal browning
in tomato
distinguished from graywall 648
incidence and sources of resistance 408
irradiation
Helminthosporium oryzae, induced mutation and cytology 439, **440**, **441**
response of several decay pathogens 474
Isaac, P. K. 474
Ivanoff, S. S. 640
Jackson, Curtis R. 190
Jaffe, M. J. (272)
Jenkins, W. R. (571), (633)
Jensen, Harold J. 640
Jensen, S. G. 640
Jewell, F. F. 48
Johnson, Howard W. (641)
Johnson, W. H. (570), 572
Jones, Henry A. (54)
Jones, John P. (263), 641
Juniperus virginiana, Sclerotium bataticola and Fusarium in, highly resistant to black root rot 653
Kahn, Robert P. 847
Kankam, J. S., Jr. 641
Kantack, E. J. (150), 447
Karle, Harry P. 466
Keitt, G. W. (88), (169), (687)
Kelman, A. (627), (645)
Kendrick, E. L. 51
Kendrick, Edgar L. 641
Kendrick, J. B., Jr. 641, (650)
Kennedy, Bill W. 641, 641
Keplinger, J. A. (239)
Kessler, K. J. 572
Kimble, K. A. 642
King, T. H. (287), (637), (641)
Király, Z. (866)
Kirkpatrick, H. C. (884)
Klarman, W. L. 868
Klein, H. Harvey 488
Kline, D. M. 642, 642
Klisiewicz, John M. 642
Klos, E. J. 412
Klotz, L. J. (83), (855)
Knutson, R. (605)
Koch, E. J. (571)
Kolbezen, M. J. (83), (634), (642)
Kollmer, G. F. 642
Konicek, Donald E. (640)
Kramer, C. L. (332)
Krebill, R. G. 642
Krupka, L. R. 643
Krusberg, L. R. 9, 643
Kuc, J. (637), (640)
Kuc, Joseph (267)
Kuhn, C. W. 643
Kuntz, J. E. (640)
Kurzman, R. H., Jr. 240
Lahr, Keith A. (627)
Laird, E. F., Jr. (327)
Lal, S. B. (709)
Lambe, R. C. (84)
Lamey, H. A. 643
Larson, R. H. (642), (659)
Latch, G. C. M. 643
late blight, in tomato, effect of nutrition and environment 574
Leach, L. D. (639), 643
Leben, Curt (88), (169), 644
legumes (forage), Thielaviopsis basicola in, technique of determining seedling reaction 638
lemon
Fusarium oxysporum in, relation to Radopholus similis in roots 635
Fusarium solani in, relation to Radopholus similis in roots 635
Radopholus similis in, movement into roots and relation to Fusarium 635
Lentz, Paul L. (570)
Leone, I. A. (239), (570)
Leone, Ida A. (186)
Letey, John, Jr. (656)
lettuce
Erysiphe cichoracearum in
effects of temperature and moisture stress 304
relation of microclimates 450
radish yellows in, symptoms 389, **391**
lettuce powdery mildew, see (under fungi) **Erysiphe cichoracearum**
Lewis, F. H. (571)
Lewis, G. D. 240, 341
lily
bulb treatment, tests of 61 chemical treatments 636
scale tip rot of, antagonism and synergism among organisms 615, **616**, **618**
lima bean
Colletotrichum truncatum in, resistance in P.I.199791 and 186984 573
Phytophthora phaseoli in, aids for forecasting 572
lime
exocortis in, effects on growth, yields, and symptoms 577
in soil, effect on incidence of Botrytis cinerea in tomato 655
lime-sulfur, on Sclerotinia laxa and S. fructicola, effect of combination with sodium pentachlorophenoxide 649
Lindberg, G. D. 457, 644
Lindner, R. C. 884
Ling, K. C. (635)
Lingappa, B. T. 644
Lingappa, Yamuna 644
Liquidambar styraciflua, Sclerotium bataticola and Fusarium in, immune to black root rot 653
Littau, Virginia C. 240
Liu, H. P. (34)
Llanos M., Carmen 826
Lockwood, J. L. (826)
Lockwood, John L. 621, (644), (644), 787
locust (black), Merulius lacrymans in, effects of environment on growth 633
Loebenstein, G. 98, 100
Loegering, W. Q. (40), (653)
Loehr, B. F. (83)
Loewenberg, J. R. 215, 322
Loos, Clive A. 383
Loos, Sarah B. (384)
loose smut
in barley, preparing embryos for examination 270
in oats, hosts for differentiating races 209
Lorentz, Paul (404)
Lownsbery, B. F. 178
Lucas, G. B. (638)
Luke, H. H. 205, 209, 576, 576, 644
Lukens, R. J. 867
Lukezic, F. L. 84
lupine, Phytophthora megasperma sojae in, cause of root and stem rot 641
lupine (white), Pleiochaeta setosa in, seed treatment 577
Lutey, Richard W. 910
Lyda, Stuart D. (790)
Lyon, H. H. 644

Lyttleton, J. W. (175)
McCain, Arthur H. (85), 85, (278)
McClendon, John H. 258
McClure, T. T. (558)
McCombs, C. L. (659)
McCrum, R. C. 241
McEwen, F. L. (654)
McKay, Hazel H. (570)
McKeen, C. D. (647)
McLean, D. M. (54), (576)
McMeekin, Dorothy 93
McMillian, W. W. (643)
McNew, George L. 511
McRitchie, John J. 645
McVey, D. (657)
McVey, Donald V. 416
Mace, M. E. (628)
Macrosiphum dirhodum, vector of radish yellows virus 389, 391
Macrosiphum granarium
vector of barley yellow dwarf, from injection of virus 647
vector of radish yellows virus 389, **391**
Macrosteles fascifrons, cytological and cytochemical studies, as vector of aster yellows 240
magnolia, new leaf spot of seedlings, association of Isariopsis sp. with 637
mahogany, Merulius lacrymans in, effects of environment on growth 633
Mai, W. F. 237, (239), (341), (644)
Maier, Charles R. 351
Maine, E. C. 645
Maloy, Otis C. 56
mango, necrosis, effect of boron 431
Mankau, R. 645
Mankin, Cleon J. (627), (627)
maple, salt injury 240
Maramorosch, Karl (240), 241
marigold
Fusarium oxysporum, isolate causing wilt of 85
Radopholus similis in, effects on nematode 577
Martin, W. J. 150, (447), (575), (639), 645
Mather, Satish C. 645
meadow nematodes, see (under nematodes) **Pratylenchus penetrans**
Melching, J. Stanley 645
Melilotus, tobacco ringspot virus in, natural occurrence 296
Meliolaceae, see under **fungi**
Menzies, J. D. (84)
metabolism, in sweet potato, effects of Ceratostomella fimbriata and poisonous chemicals 30
microflora, air-borne, growing seedlings free of 644
Micrutalis calva, occurrence on Long Island, N. Y., close relative of vector of pseudo-curly-top virus 241
Middleton, J. T. (570)
Milbrath, J. A. (312), 495
mildew, see (under fungi) **Pseudoperonospora humuli**
milkweed, virus X-disease in, natural infection 636
Miller, C. W. 645
Miller, H. N. (648)
Miller, Lawrence P. 646, 646
Miller, Paul R. 869
Millikan, D. F. (630)
mint
Puccinia menthae in, control with nickel salts 866
Verticillium albo-atrum in, determining levels of resistance 569
Minton, Earl B. 576, 576
Minton, Norman A. 784
Mirocha, C. J. 646, 646
Mishanec, W. (654)
mistletoe (dwarf), on red and white fir, host specialization in California 650
Mohamed, Hosni A. 339, 400
Molnár, G. (866)
Monson, A. M. 646
Moore, B. J. (575)
Moorhead, Ellen L. (34), (627), 646
Morehart, A. L. (570)
Morey, D. D. (209), (576)
Morgan, Max E. (632)
morning glory, sweet potato virus in, seedlings as indicators 571
Morton, Donald J. 270, 647
Moseman, J. G. 647, 647, 736
Mountain, W. B. 647
Mueller, Kenneth E. 85
Muir dwarf, evidence that cause is stone fruit ringspot virus 380
mulberry (white), Merulius lacrymans in, effects of environment on growth 633
Munnecke, Donald E. 647, 696
Murakishi, H. H. 605
Murakishi, Harry H. 408, 464, 648
Murphy, H. C. (657), (779)
muskmelon, Geotrichum candidum in, susceptible to most isolates tested 665, **667, 668, 671**
mustard, cauliflower mosaic virus in, purification and properties 651
Myzus ornatus, vector of radish yellows virus 389, **391**
Myzus persicae, vector of radish yellows virus 389, **391**
Nandina domestica, cucumber mosaic virus in, symptoms, virus characteristics, and vector 569
Narvaes, Ignacio (630)
Nash, Shirley M. (137), 772
Natour, R. M. 648
Natti, J. J. 241
Nayudu, M. V. 360, 648
Neal, A. L. (612)
neck rot in onion, see (under onion) **Botrytis allii**
nectarine, Sclerotinia in, relative pathogenicity of S. fructicola and S. laxa 550, **556**
Neely, Dan 648
Nelson, Paul E. 356, (445)
Nelson, R. R. 158, 375, 648, 649, (652), 774
Nelson, Ray 648, 648
nematodes
Aphelenchoides bicaudatus, in coffee in Guatemala 631
Aphelenchoides coffeae, in coffee in Guatemala 631
Aphelenchoides ritzema-bosi, in alfalfa, culturing, histopathology, and biochemistry 643
Aphelenchus avenae, in coffee in Guatemala 631
associated with roots, population variations 633
Belonolaimus longicaudatus
in grapefruit, effects on roots 152, **154**
in peanut, recent control developments 632
Caternaria in, virulent to several different genera 629
Criconemoides
in peach, preplant control 575
in rose, control with root dip treatments 659
Criconemoides curvatum
in carnation
observation box for on living roots 573
parasitism and pathogenicity 656
Criconemoides ornatum, in cotton, effect of resistant and susceptible vars. on population 784
Ditylenchus destructor, in potato, symptom development during storage 83
Ditylenchus dipsaci
enzymes of 9
extraction technique, from soil and onion scales 240
in alfalfa, culturing, histopathology and biochemistry 643
in onion, extraction from scales 240
overwintering and migration 341
Ditylenchus procerus, in coffee in Guatemala 631
Ditylenchus triformis, enzymes of 9
Helicotylenchus erythrinae, in coffee in Guatemala 631
Helicotylenchus nannus
in cotton, population build-up and pathogenicity 576

nematodes Helicotylenchus nannus (continued)
in pine, relation to stunting 652
in soybean, population build-up and pathogenicity 576
in tomato, population build-up and pathogenicity 576
survival in soil, effect of storage temperatures 635
Heterodera, in potato, reactions to resistant and susceptible selections 638
Heterodera glycines
in cotton, evaluation of rotation and fumigation 635
in soybean, effect of soil temperature 652
Heterodera rostochiensis, hatching, stimulant for 612
Heterodera trifolii, in clover, in leaves 866, **867**
Hoplolaimus tylenchiformis
in cotton
effect of resistant and susceptible vars. on population 784
population build-up and pathogenicity 576
in pine, relation to stunting 652
in soybean, population build-up and pathogenicity 576
in tomato, population build-up and pathogenicity 576
in banana, preparing nematode-free seed 383, **384**
Meloidodera, in pine, relation to stunting 652
Meloidogyne, in citrus in Taiwan and New Delhi 631
nematode-trapping fungi for control 645
Meloidogyne arenaria
in clover (red), population development 631
in peach, preplant control 575
in sweet potato, reaction of 8 selections 575
larvae, effect of hot water 658
Meloidogyne exigua, in coffee in Guatemala 631
Meloidogyne hapla
in alfalfa, effect on growth 181
in gardenia, effects 633
in red clover, effect on growth 181
in sweet potato, reaction of 8 selections 575
in tomato
differentiation through host reaction from M. incognita incognita and Nacobbus batatiformis 874, **875**
influence of soil moisture stresses, 319, **320**
larvae, effect of hot water 658
survival in soil, effect of storage temperatures 635
Meloidogyne incognita
host specificity and perineal patterns, variation in 724, **725, 727, 729, 731-733**
in alfalfa, effect on growth 181
in peach, preplant control 575
in red clover, effect on growth 181
in sweet potato, reaction of 8 selections 575
larvae, effect of hot water 658
oxygen tolerance 656
Meloidogyne incognita acrita
in cotton
complication in inheritance of resistance to Fusarium oxysporum vasinfectum 44
effect of resistant and susceptible vars. on population 784
population build-up and pathogenicity 576
resistance in Upland seedlings 673, **673, 675**
in gardenia, effects 633
in gladiolus, influence of preplanting and row treatments 574
in peach, preplant control 575
in soybean
population build-up and pathogenicity 576
histopathology 442, **445**
in sweet potato, reaction of 8 selections 575
in tobacco
effect on black shank 899, **901, 903, 905**
resistant line released to breeders 575
in tomato
mechanism of accumulation around seedlings 178, **178**
population build-up and pathogenicity 576
larvae, effect of hot water 658
Meloidogyne incognita incognita
in cotton, population build-up and pathogenicity 576
nematodes Meloidogyne incognita incognita (continued)
in cucumber, physiological and biochemical studies on galls 650
in gardenia, effects 633
in soybean
histopathology 442, **445**
population build-up and pathogenicity 576
in tobacco, effect on black shank 899, **901, 903, 905**
in tomato
differentiation through host reaction from M. hapla and Nacobbus batatiformis 874, **875**
physiological and biochemical studies on galls 650
population build-up and pathogenicity 576
root galls and behavior of second-stage larvae 322, **322**
Meloidogyne javanica
in peach, preplant control 575
in sweet potato, reaction of 8 selections 575
in winter cereals, effect of cereals on population level 657
larvae, effect of hot water 658
Nacobbus batatiformis, in tomato, differentiation through host reaction from Meloidogyne hapla and M. incognita incognita 874, **875**
Panagrellus redivivus, nematophagous fungi on, predacious activity and growth 577
photographs of, high-resolution continuous-tone 644
Paratylenchus macrophallos, in coffee in Guatemala 631
Pratylenchus
in cherry
elimination from roots with diazinon 654
elimination from roots with thimet 654
in orchid, elimination from roots with thimet 654
in peach, preplant control 575
in rose
control with root dip treatments 659
elimination from roots with thimet 654
Pratylenchus brachyurus, in cotton, effect of resistant and susceptible vars. on population 784
Pratylenchus coffeae, in coffee in Guatemala 631
Pratylenchus penetrans
0,0-diethyl-S-(ethylthioethyl) phosphorodithioate with, effects on population 640
in apple, seedling growth in response to inoculation 237
in cherry, elimination from roots with diazinon 654
in eggplant, effect on Verticillium wilt incidence 647
in pea, population increase related to vegetative growth 239
in strawberry, effect on plant growth 239
movement, feeding, and hatching, time-lapse studies 570
population variations 633
survival in soil, effect of storage temperatures 635
Pratylenchus pratensis, in alfalfa, effects of nematocides on nematode and host yields 656
Pratylenchus vulnus, in rose, elimination from roots with dimethoate, Phosphamidan, and Ortho-dibromo 8 654
Pratylenchus zeae, enzymes of 9
Radopholus similis
in host-free soil, longevity 656
in lemon, movement into roots and relation to Fusarium 635
in marigold, effects on nematode 577
recovery from roots by enzyme preparations 634
Rotylenchus brachyurus
in cotton, population build-up and pathogenicity 576
in soybean, population build-up and pathogenicity 576
in tomato, population build-up and pathogenicity 576
Rotylenchus robustus
in nursery plants, association with decline 656
Rotylenchulus reniformis
in cotton, population build-up and pathogenicity 576
in soybean, population build-up and pathogenicity 576
in tomato, population build-up and pathogenicity 576
soil fumigants on, effect on occurrence in field bins 576
soybean cyst, control by crop rotation 652
Trichodorus, in peach, preplant control 575
Trichodorus christiei

nematodes Trichodorus christiei (continued)
in coffee in Guatemala 631
in cotton, effect of resistant and susceptible vars. on population 784
in grapefruit, effects on roots 152, **154**
oxygen tolerance 656
pathogenicity trials 639
Tylenchulus semipenetrans, oxygen tolerance 656
Xiphinema, in peach, preplant control 575
Xiphinema americanum
in coffee in Guatemala 631
in forage crops, only known Dorylaimoidea associated with in New York 658
in pine, relation to stunting 652
oxygen tolerance 656
new species, varieties, strains, etc.
Aspergillus niger var. nov. floridanus, proposed for cause of stem rot of Dracaena sanderiana 648
bacteria, cause of hairy root of field roses 647
bacteria, possible cause of bacterial petiole spot of celery 648
bacterium, Pseudomonas pastinacae, cause of bacterial brown rot of parsnip roots 280, **281**
bean virus from Mexico, severe bean mosaic 334, **335, 336**
Fusarium oxysporum f. sedi n.f., cause of Fusarium wilt of Sedum 651
Helminthosporium dictyoides f. sp. dictyoides n.f., physiologic form from meadow and tall fescues 691, **693**
Helminthosporium dictyoides f. sp. perenne n.f., physiologic form from perennial and annual ryegrasses 691, **693**
tetrin, antifungal antibiotic produced by a Streptomyces sp. 817
vein necrosis virus, new strain of alfalfa mosaic virus in bean 226, **229**
viruses
necrotic ringspot in blueberry 241
possibly new virus in bean, wide host range 655
severe bean mosaic, a new bean virus from Mexico 334, **335, 336**
Newhall, A. G. (76)
Newsom, L. D. (447)
Nichols, Carl W. 649, (658)
Nielsen, L. W. 649, 840
Novotny, Helen M. (650)
nutrition
boron, effect on tobacco mosaic virus multiplication in tobacco 26, **27**
effect on tobacco mosaic virus multiplication in tobacco 26, **27**
Fusarium solani phaseoli, effect of nitrogen sources and glucose on pathogenicity 137, **138, 139**
nitrogen, relation to Helminthosporium oryzae in rice 434, **437**
Nyland, George 85, 380
oak
Ceratocystis fagacearum in, distribution in roots 775
salt injury 240
oak (Chinese), Ceratocystis fagacearum in, effect of temperature and moisture on wilt 640
oak (northern red), Merulius lacrymans in, effects of environment on growth 633
oak wilt fungus, see (under fungi) **Ceratocystis fagacearum**
oat
barley yellow dwarf virus in, transmission by aphids made viruliferous by injection 647
crown rust in
resistance to separated from susceptibility to Helminthosporium victoriae 205, **206, 208**
sources of resistance 654
varieties resistant to race 264, 657
Helminthosporium gramineum group in, morphology, physiology, and pathology 688
Helminthosporium sativum in, pathogenic specialization 627
Helminthosporium victoriae in, susceptibility to separated from resistance to crown rust 205, **206, 208**
oat (continued)
hoja blanca virus in, transmission by Sogata orizicola 643
loose smut in, hosts for differentiating races 209
Meloidogyne javanica in, effect of host on nematode population level 657
Puccinia coronata avenae in
host-parasite interactions of race 202 in 8 vars. 914, **915, 917**
inheritance of resistance of C.I.7232, a derived tetraploid 779
inhibition by antibiotic produced by Streptomyces sp. 841
Puccinia graminis avenae in, altering effect of resistance genes 630
residues of, effect on soil fungi 22
Victoria blight of, inheritance and linkage studies 644
Victoria-type crown rust of, resistance, inheritance and linkage studies 644
yellow dwarf virus in, effect on winter killing 84
oat loose smut, races of Southeastern U. S. 576
obituaries
Howard Austin Edwon, 1875-1960 869
Takewo Hemmi, 1889-1959 687
Louis Otto Kunkel, 1884-1960 777
Gerardo Offimaria Ocfemia, 1891-1959 403
Ocfemia, Gerardo Offimaria, biographical sketch 403
Ogawa, Joseph M. (82), 85, 278, 550, 649, 790
Olsen, Carl M. (82), 85
onion
Botrytis in, cause of blast 76, **76, 77**
Botrytis allii in, influence of growing, curing, and storage 87
onion blast, see (under fungi) **Botrytis**
orange
exocortis in, effects on growth, yields, and symptoms 577
Penicillium digitatum in, effects of volatile fungicides in packages 855
Penicillium italicum in, effects of volatile fungicides in packages 855
Thielaviopsis basicola in, effect of temperature on pathogenesis 657
orchid
Erwinia cypripedii in, cause of bacterial brown rot 182
Pratylenchus in, elimination from roots with thimet 654
Orlob, G. B. 649
Osage orange, Merulius lacrymans in, effects of environment on growth 633
Ostazeski, Stanley A. 577
Oswald, John W. 504
Owens, Robert G. 649, 650
Pack, M. R. (639)
Pady, S. M. 332
Palmer, H. C. (650)
Palmer, John G. 572, 572, 572
Papavizas, G. C. 516, (522), 650, 650
Pappelis, A. J. 650
Parker, K. G. (412)
Parmeter, J. R. 650
parsnip, bacterial brown rot, caused by new bacterium: Pseudomonas pastinacae 280, 281
Patil, S. S. 85, 386
Patino, Graciano (226), (334)
Patton, R. F. (642)
Paulus, A. O. (628)
Paulus, Albert O. 650
pea
Aphanomyces euteiches in
introductions with partial resistance 621
penetration of roots by zoospores 632
soil indexing and effect of rot on yield 287, **287**
bean virus 2 in, reversal of dominance in resistance 654
Fusarium solani pisi in
commercial varieties tested for reaction 637
soil indexing and effect of rot on yield 287, **287**
Pratylenchus penetrans in, population increase related to

pea Pratylenchus penetrans in (continued)
vegetative growth 239
streak virus in, wide host range 654
peach
Cytospora rubescens in, pathogenic variation of isolates 86
Geotrichum candidum in, susceptible to most isolates tested 665, **667**, **668**, **671**
necrotic leafspot of, evidence that cause is stone fruit ringspot virus 380
nematodes in, identification and preplant control 575
Penicillium funiculosum in, strain causing a wilt disease 161, **161**
Rhizopus stolonifer in, effect of postharvest temperature and moisture 558
rusty spot in, control with sulfur 239
Sclerotinia in, relative pathogenicity of S. fructicola and S. laxa 550, **556**
stunt, evidence that cause is stone fruit ringspot virus 380
Western X-disease virus in, effect on free amino acids and amides 141
peanut
Belonolaimus longicaudatus in, recent control developments 632
mycoflora of, in storage 220
Sclerotium rolfsii in, comparative rot development in 2 varieties 575
pear
Penicillium funiculosum, strain causing a wilt disease 161, **161**
Phytophthora cinnamomi in, possible cause of quick collapse 630
pecan
Fusicladium effusum in
physiologic specialization 527
protectant fungicides 574
Pelletier, E. Neil 650
pepper
Alternaria melongenae in, influence of substrate on spore size 486
Cercospora capsici in, effect of fertilization 577
necrotic pod streak of, induction by tobacco mosaic virus 464, **465**
Phytophthora capsici in, resistance in 613 lines, varieties, or plant introductions 642
potato virus X in, natural occurrence in California 650
potato virus Y in
a mutation for resistance 632
Cytovirin effects on susceptibility and transmissibility 109
genetics of resistance 364
inheritance of resistance 73
tobacco etch virus in
genetics of resistance 364
pathological histology 658
tobacco mosaic virus in
effect of air temperature on multiplication 803, **804**, **805**
induction of necrotic pod streak 464, **465**
Xanthomonas vesicatoria in
effect of fertilization 577
screening for resistance 577
variability in Florida 657
Perlasca, Gerardo 889
Perry, Bruce A. (54)
Perry, V. G. (152)
Petersen, Larry J. 86
Peterson, Joseph L. 807
Peterson, R. S. 876
Pfahler, P. L. (576), (644)
Phillips, D. J. 651
Physalis angulata, Pseudomonas solanacearum in, relation to bacterial wilt of banana 660, **662**, **663**
pine
Cronartium fusiforme in, inoculation techniques 48, **49**, **50**
Cronartium ribicola in
germination of sporidia 61, **63**, **64**, **67**
inoculations in mist chambers 657
pine (continued)
decline, organisms found in association with 643
Lophodermium in, symptoms 628
Merulius lacrymans in, effects of environment on growth 633
nematodes in, relation to stunting 652
Peridermium harknessii in, development of western gall rust 876, **877**, **878**
Poria incrassata in, spread through soil to 571
salt injury 240
Sclerotium bataticola and Fusarium in, 11 species rated susceptible 653
Pine, T. S. 701
Pirone, T. P. 651
plant injury
induced by atmospheric ozone 639
plum, crinkle leaf in, caused by genetic instability 701, **701**, **702**
poinsettia, Thielaviopsis basicola in, influence of pH on root rot 628
Poncirus trifoliata, exocortis in, influence of host nutrition 87
poplar (yellow), Verticillium dahliae in, symptoms 572
Porter, Clark A. 651
Porter, F. M. (657)
potato
black root, see (under potato) **Meliolaceae**
Ceratocystis fimbriata in, changes in host proteins 655
Ditylenchus destructor in, symptom development during storage 83
golden nematodes in, reactions to resistant and susceptible selections 638
Meliolaceae in, morphology and host range 84
Phytophthora infestans in
nature of partial resistance of 3 species 637
scopolin produced in host 398
potato virus F in
latent in imported variety 460, **462**
resistance in interspecific hybrid 460, **462**
soft-rot decay, freshly harvested tubers in air-tight containers 649
Verticillium albo-atrum in
amount in Idaho certified seed 84
relation of plant age to infection 86
role of pectic enzymes in resistance 633
virus X in
carbohydrate reserves in resistant plants 629
isolation from immune varieties 231
potato virus Y
in pepper
inheritance of resistance 73
Cytovirin effects on susceptibility and transmissibility 109
Pote, Hugh L. (817)
Pound, G. S. (290), (651)
Pound, Glenn S. (26), (196), 500, (642), (797), 803, (807)
powdery mildew, of Rosa wichuriana, effects of phaltan and actidione on 572
powdery mildew, see (under wheat) **Erysiphe graminis tritici**
Powell, Dwight (657), (685)
Powelson, R. L. 491
Powers, H. R., Jr. 454, (653)
Pringle, Ross B. 324
Provvidenti, R. (654), (654)
prune dwarf, evidence that cause is stone fruit ringspot virus 380
prune
Cytospora rubescens in, pathogenic variation of isolates 86
Sclerotinia in, relative pathogenicity of S. fructicola and S. laxa 550, **556**
Prunus
leaf tissue, diribonucleic acid content 630
Sclerotinia fructicola in, effect of sodium pentachlorophenoxide and lime-sulfur 649

Prunus (continued)
Sclerotinia laxa in, effect of sodium pentachlorophenoxide and lime-sulfur 649
Pryor, R. L. (572)
Purdy, L. H. 651
Purdy, Laurence H. 581
Qasem, Subhi A. 703
Raabe, Robert D. (638), 651
radish
Fusarium oxysporum conglutinans in, resistance 807, **811**, 813
radish yellows in, symptoms 389, **391**
Rangaswami, G. 486
Raniere, L. C. (241)
Rappaport, Irving (659)
ratoon stunting, see under **sugarcane**
Raymer, W. B. 312
Rebois, R. V. (635)
Reeves, E. L. (188)
Reiling, T. P. 287
Reinert, R. A. 652
Reinhart, J. H. (239)
Reinhardt, Jack F. 585
Renfro, B. L. (628)
residues, crop, effect on soil fungi and seedling blights 22
Rhamnus palaestina, effect on origin and persistence of Puccinia coronata avenae 562
Rhopalosiphum fitchii, vector of barley yellow dwarf, from injection of virus 647
rice
Helminsthosporium oryzae in, relation of nitrogen to disease 434, **437**
virus inhibitors in 847
Rich, Saul (421), (640)
Richardson, Lloyd T. 651
Richter, Erna (646)
Riker, A. J. (587), (657)
Ristich, S. S. (239)
Roane, C. W. (40)
Robert, Alice L. 217, 261
Roberti, C. 241
Rochow, W. F. (647), 881
Rogers, W. E. 652
Roistacher, C. N. 855
Roncadori, R. W. 573
root rot, see (under fungi) **Aphanomyces euteiches** and **Fusarium solani pisi**
rose
Criconemoides in, control with root dip treatments 659
Diplocarpon rosae in
control with fungicide-acaricide combination 573
leaflet assay of susceptibility 572
hairy root of, bacterium causing 647
powdery mildew in, effects of phaltan and actidione 572
Pratylenchus in, control with root dip treatments 659
Pratylenchus in, elimination from roots with thimet 654
Pratylenchus vulnus in, elimination from roots with dimethoate, Phosphamidan, and Ortho-dibromo 8 654
rose mosaic virus in, heat treatment 240
Rosenberg, Dan Y. (649), (658)
Ross, A. F. (647)
Ross, A. Frank 652
Ross, J. P. 652, 652, 866
Rothman, P. G. 914
Rothrock, J. W. (841)
Rowan, S. J. 653
Rowell, J. B. (627), 653
Rubis, D. D. (129)
Ruehle, John L. 652
Rumex acetosella, tobacco ringspot virus in, isolated from symptomless host 296
rust
in bean
effect of postinoculation temperatures 653
rust in bean (continued)
local necrosis associated with 653
rust, crown, in oats, sources of resistance 654
rusty spot, in peach, control with sulfur 239
rye
Helminthosporium sativum in, seed treatment 576
hoja blanca virus in, transmission by Sogata orizicola 643
Meloidogyne javanica in, effect of host on nematode population level 657
Sitophilus oryzae in, seed treatment 576
ryegrass, Pythium aphanidermatum in, effects of temperature 575
Sadanaga, K. 779
safflower, Phytophthora drechsleri in, development of resistant varieties 129, **129**
Sambandam, C. N. (486)
Sando, W. J. (454)
Santiago, Alma (865)
Sasser, J. N. (632), (652), (724)
Savage, E. J. 573, 653
Schaller, C. W. 653, (736)
Scharen, Albert L. 274
Scharpf, R. F. (650)
Scheffer, R. P. 192
Schein, Richard D. 653, 653
Schlegel, David E. 156
Schmitthenner, A. F. (22)
Schnathorst, W. C. 304, 450, 653
Scholes, J. Fred (86)
Schreiter, S. (562)
Schroeder, W. T. 654, 654
Schuster, M. L. (215), (322), 874
Sedum, Fusarium wilt of, caused by Fusarium oxysporum sedi n.f. 651
Segall, R. H. 76
Semeniuk, P. (572)
Semeniuk, Peter (572)
Sen, C. (431)
Sequeira, Luis 654
sesame, Corynespora in, species pathogenic apeared identical to C. cassiicola 263, **265**
Sewell, William D. 654
Shands, H. L. 654
Shaw, C. G. (84)
Shay, J. R. (91)
Shepherd, Robert J. 26, 195, 797
Sher, S. A. 654
Shigo, A. L. 655
Shimomura, Toru, 344
Siegel, Albert 86, 89
Siegel, M. R. 680
Sigatoka leafspot, see (under fungi) **Mycosphaerella musicola**
Sill, W. H., Jr. (632), 709
Silverman, William 114, 130
Simons, John N. 109, 424
Simons, M. D. (657)
Sims, Asa C., Jr. 282
Sinclair, J. B. 577, 655
Singh, G. P. 290, (803)
Sisler, Hugh D. (569), (830)
Sitophilus oryzae, in rye, seed treatment 576
Sitterly, W. R. 91
Skotland, C. B. 655, 655
Sloneker, J. H. (594)
Smiley, J. H. 655
Smith, A. L. 44, (784)
Smith, Albert L. (576), (576)
Smith, F. G. (650)
Smith, Floyd F. (569)
Smith, M. A. (474)
Smith, Richard S. (628)
Smith, W. L., Jr. 558
Smith, Wilson L., Jr. (634)
smuts, Kansas aeromycology 332

snapdragon
blight of, caused by Cercospora antirrhini 190, **191**
Cercospora antirrhini in, cause of stunting and defoliation 190, **191**
Puccinia antirrhini, effect of temperature on fungitoxicant action 242
snapdragon rust, see (under fungi) **Puccinia antirrhini**
Snyder, William C. (137)
Sogata orizicola, vector of hoja blanca virus, transmission to hosts besides rice 643
soil fungi, effect of growing crops and crop residues on 22
soil rot, see (under speet potato) **Streptomyces ipomoea**
Solberg, R. A. (615)
Somers, G. Fred (258)
sorghum, Helminthosporium sativum in, pathogenic specialization 627
sour cherry yellows, evidence that cause is stone fruit ringspot virus 380
Sowell, Grover, Jr. 577
soybean
Cercospora kikuchii in, control on seed 570
cyst nematode in, control by crop rotation 652
Diaporthe phaseolorum sojae in, control on seed 570
Helicotylenchus nannus in, population build-up and pathogenicity 576
Heterodera glycines in, effect of soil temperature 652
Hoplolaimus tylenchiformis in, population build-up and pathogenicity 576
Meloidogyne incognita acrita in
histopathology 442, **445**
population build-up and pathogenicity 576
Meloidogyne incognita incognita in
histopathology 442, **445**
population build-up and pathogenicity 576
residues of, effect on soil fungi 22
Rotylenchus brachyrus in, population build-up and pathogenicity 576
Rotylenchulus reniformis in, population build-up and pathogenicity 576
spinach
cucumber virus 1 in
resistance to, new source 54
strain infectious to blight-resistant varieties 7
leaf spotting, from ozone and other air-borne oxidants 570
radish yellows in, symptoms 389, **391**
sensitive to atmospheric ozone 639
spinach blight, see (under viruses) **cucumber virus 1**
Sprague, G. F. (261)
spruce, Pholiota alnicola and P. squarrosa in, associated with root and butt rots 633
squash
extracts from healthy plants, antigenic analysis 646
Stahmann, M. A. (198), (367), (370)
Stahmann, Mark A. (633), 655
Stakman, E. C. (40)
stalk rot
in corn, rating index 146, **148**
Stall, Robert E. 655, (657)
Standifer, Marie S. 152
Staples, Richard C. 573, 656
Starr, Mortimer P. (182)
Steere, R. L. 656
stem rust, in wheat, effect of light and temperature on reaction 645
stem rust, see (under fungi) **Puccinia graminis tritici**
Stessel, G. J. (240), 656, **656**
Stevens, Russell B. 508
Stewart, D. M. (40)
Stokes, G. W. (638), (655), 770
Stolzy, L. H. 656
stone fruits
Cytospora canker in trees, occurrence in California 84
Cytospora rubescens in, pathogenic variation of isolates 86
Pseudomonas syringae in, source of the inoculum 634
Stone, William J. 263
strawberry
angular leafspot of, a new disease 641
Botrytis cinerea and other organisms in, influence of fungicides on 657
Botrytis cinerea in, initiation of fruit rot 491, **492, 493**
Colletotrichum fragariae in, associated with summer killing 575
Pratylenchus penetrans in, effect on plant growth 239
viruses of, dissemination in Arkansas 477
Stretch, A. W. 241
Streu, H. T. 573, 656
Strider, D. L. 583, 781
Strobel, J. W. 86
Struble, F. Ben (574), (673), (822)
Subba-Rao, N. S. 763
sugar beet
p-dimethylaminobenzenediazo sodium sulfonate on, uptake and translocation by seedlings 639
Pythium ultimum in, protection by seed and soil fungicides 643
radish yellows in, symptoms 389, **391**
Rhizoctonia solani in, protection by seed and soil fungicides 643
sugarcane, ratoon stunting, viruslike particles associated with 635
Sullivan, T. (215), (322), (874)
Sutton, Donald D. 182
Swain, T. (398)
sweet potato
Ceratostomella fimbriata in, metabolic alterations induced by 30
Diaporthe batatatis in, effect of bed temperature and seed dip on incidence of sprout decay 186
feathery mottle in, complex of 3—yellow dwarf, internal cork, and leafspot 751, **753**
internal cork virus in
analysis for in serial nodes of stems 645
control by isolation 150
elimination by culturing apical meristems 840
part of feathery mottle complex 751, **753**
relation of insects to in Louisiana 447
leaf pucker virus in, in Israel 100, **101, 103**
leafspot virus in, part of feathery mottle complex 751, **753**
Meloidogyne in, reaction of 8 selections to 5 spp. 575
metabolic alterations, induced by chemicals and Ceratostomella fimbriata 30
ringspot virus in
identifying wtih paper chromatography 98, **98**
in Israel 100, **101, 103**
Streptomyces ipomoea in
evaluating lines 574
methods determining reaction of lines to 822, **823-825**
sweet potato virus in, seedlings as indicators 571
tobacco ringspot in, masked strain found 571
vein-clearing virus in
identifying with paper chromatography 98, **98**
in Israel 100, **101, 103**
viruses in, in Israel 100, **101, 103**
yellow dwarf virus in, part of feathery mottle complex 751, **753**
sycamore, Gnomonia veneta in, early stage of anthracnose 648
symposium, training for the future in plant pathology 500
Tammen, James (356)
Tape, Norman W. 163
Taraxacum officinale, tobacco ringspot virus in, isolated from symptomless host 296
Tarjan, A. C. 577, 577, 656
Taxodium distichum, Sclerotium bataticola and Fusarium in, immune to black root rot 653
Taylor, J. 577
techniques

techniques (continued)
culture and storage of Phytophthora sojae, frozen-lima-bean agar for 136
detecting viable mycelium, after seed treatment against Ustilago nuda 647
determining seedling reaction, Thielaviopsis basicola in forage legumes 638
differential synthetic media, to separate Phytophthora spp. pathogenic to citrus 83
embryo examination, for loose smut of barley 270
evaluating lines, sweet potato for reaction to Streptomyces ipomoea 574
fumaric acid determination in hull rot of almond 646
fumigation, a two-bottom two-way plow sole fumigator 83
growing seedlings, free of air-borne microflaro 644
indexing, bark patch grafts for stem-pitting virus in apple 241
isolation
actinomycetes that produce diffusible antifungal antibiotics 88, **88**
Phytophthora cinnamoni from tissue and soil 87
superior media for actinomycetes from soil 644
victoxinine from cultures of Helminthosporium victoriae 324
measurement, fumigant concentrations 642
nematode extraction
from soil and onion scales 240
from roots by enzyme preparations 634
observation box, for nematodes on living roots, 573
paper chromatography, identifying ringspot and vein-clearing viruses in sweet potato, 98, **98**
photography, high-resolution continuous-tone photographs of nematodes 644
spray for evaluating oil control of Mycosphaerella musicola in banana 69, **71**
steaming soil, aerated steam 82
whole-mount for studing infected leaves 474, **475**
Teliz-Ortiz, Moises 119
Tetranychus telarius, in rose, control with fungicide-acaricide combination 573
Thayer, Paul 212, 657
Theis, T. (69), (865)
Theis, Thomas 657
Thomas, C. A. 129, 473
Thomas, H. Rex (574)
Thomason, Ivan J. 1, 657
Thorn, G. D. (651)
Thorn, W. A. (87)
Thurston, H. David (637)
tobacco
alfalfa mosaic virus in, specific infectivity changes 643
extracts from healthy plants, antigenic analysis 646
heat-induced abnormalities, a model disease 629
Meloidogyne incognita acrita in
effect on black shank 899, **901, 903, 905**
resistant line released to breeders 575
Meloidogyne incognita incognita in, effect on black shank 899, **901, 903, 905**
Phytophthora parasitica in, effect of Meloidogyne on black shank 899, **901, 903, 905**
Pseudomonas solanacearum in
oxidation rates of polyphenols and ascorbic acid in stem tissue 645
virulence from avirulent-virulent mixtures 627
Pseudomonas tabaci in
behavior of resistance locus in Burley 21 and Ky 61 770
population studies in plants of varying resistance 655
sensitive to atmospheric ozone 639
tobacco mosaic virus in
competition between two strains 659
difference of Nicotiana glauca form from dominant form 497, **498**
effect of plant nutrition on virus multiplication 26, **27**
improved resistance 572
induced resistance from infection 652
tobacco tobacco mosaic virus in (continued)
lesion size and timing from two strains 677
magnesium effect on multiplication 195, **196**
release and preservation by roots 111
strain interference 86
topical susceptibility 659
virus-host relations in tissue culture 587, **588, 589**
tobacco necrosis virus in, topical susceptibility 659
Tolmsoff, W. J. (643)
Tolmsoff, Walter J. 86
tomato
blossom end rot of, effect of calcium and molybdenum 655
Botrytis cinerea in, incidence changes from liming the soil 655
bunchy top of, with crease stem 577
Cladosporium fulvium in, resistance of varieties 637
crease stem of, with bunchy top 577
extracts from healthy plants, antigenic analysis 646
Fusarium in, mechanics of water transport in 634
Fusarium cubense in, role of pectic enzymes in resistance 633
Fusarium lycopersici in, role of pectic enzymes in resistance 633
Fusarium oxysporum in, a calcium requirement for growth-regulator-induced resistance 625, **626**
Fusarium oxysporum lycopersici in, respiratory responses to 192
Geotrichum candidum in, strains from various sources 665, **667, 668, 671**
graywall in
distinguished from internal browning 648
incidence and sources of resistance 408
Helicotylenchus nannus in, population build-up and pathogenicity 576
Hoplolaimus tylenchiformis in, population build-up and pathogenicity 576
internal browning
distinguished from graywall 648
incidence and sources of resistance 408
late blight, effect of nutrition and environment 574
Meloidogyne hapla in
differentiation through host reaction from M. incognita incognita and Nacobbus batatiformis 874, **875**
influence of soil moisture stresses 319, **320**
Meloidogyne incognita acrita in, mechanism of accumulation around seedlings 178, **178**
Meloidogyne incognita incognita in
differentiation through host reaction from M. hapla and Nacobbus batatiformis 874, **875**
physiological and biochemical studies on galls 650
population build-up and pathogenicity 576
root galls and behavior of second-stage larvae 322, **322**
Nacobbus batatiformis in, differentiation through host reaction from Meloidogyne hapla and M. incognita incognita 874, **875**
Pseudomonas solanacearum in, relation to bacterial wilt of banana 660, **662, 663**
Rhizoctonia fruit rot of, control tests in laboratory, greenhouse, and field 570
Rotylenchus brachyurus in, population build-up and pathogenicity 576
Rotylenchulus reniformis in, population build-up and pathogenicity 576
Sclerotium rolfsii in, control with chemicals and crop rotation 577
tobacco mosaic virus in
distinguishing internal browning from graywall 648
effect on yields 235
field occurrence 628
four pathogenic strains 645
inactivation in seed 627
Verticillium albo-atrum in, role of pectic enzymes in resistance 633
Xanthomonas vesicatoria in
influence of temperature and host age and nutrition 360

tomato Xanthomonas vesicatoria in (continued)
physiology of bacterial spot 648
variability in Florida 657
Tomiyama, Kohei (655)
Tousscun, T. A. 137
Toxoptera graminum, transmission of barley yellow dwarf virus, specialization among collections 881, **882**
training for future in plant pathology 500
Transtrum, L. G. (639)
Travis, R. V. 573
Trione, E. J. 480, 482
Treshow, M. (639)
Treshow, Michael 86
Triantaphyllou, A. C. 724
True, R. P. (572), (573)
Tsao, Peter H. 86, 88, 169, 657, 717
Tuite, J. (34), (711)
Tuite, John 296
Tweedy, Bill G. 657
Ullstrup, A. J. 906
Uritani, I. 30
Uritani, Ikuzo (655)
Uritani, M. (30)
Vaartaja, O. 870
Van Arsdel, E. P. 657
van Diepen, J. R. 795
Van Gundy, S. D. (86), (656), (657)
Varney, E. H. 241, (308)
vascular wilt of carnation, see (under carnation) **Fusarium oxysporum dianthi** and **Pseudomonas** caryophylli
Vaughan, Edward K. 87, 657
Victoria blight, of oats, inheritance and linkage studies 644
Victoria-type crown rust, of oats, resistance, inheritance and linkage studies 644
Viglierchio, D. R. (178)
viruslike particles associated with ratoon stunting of sugarcane 635
viruses
alfalfa mosaic
in bean, new strain, vein necrosis 226, **229**
in soybean, poor host to insect vector 627
in tobacco, specific infectivity changes 643
strains of, antigenic characteristics and relations 34, **35**
transmission by phenol-water extracts of tissue 156
unnamed strain, inhibitors of in rice 847
alfalfa yellow mosaic, inhibitors of in rice 847
aster yellows, vector of, cytological and cytochemical studies 240
barley stripe mosaic
in barley, effect of temperature and host age on disease and seed infection 290, **292**
in barley, effect of temperature on concentration 641
in corn, effect of temperature and host age on disease and seed infection 290, **292**
in wheat, effect of temperature and host age on disease and seed infection 290, **292**
inhibitors of in rice 847
stability, effects of salts, detergent, and a barley-juice factor 629
barley yellow dwarf
barley resistance to, survey of world collection for 653
in oats, transmission by aphids made viruliferous by injection 647
transmission, specialization among green bugs 881, **882**
bean common mosaic, inhibitors of in rice 847
bean red node, inhibitors of in rice 847
bean virus 2, in pea, reversal of dominance in resistance 654
bean yellow mosaic
in clover (red)
population necrotic-spotting 633
clones resistant to four isolates 323
blueberry stunt, wild sources in New Jersey 308, **310, 311**
brome mosaic
antigens, serologic and biologic properties 638
viruses brome mosaic (continued)
assay hosts, Datura stramonium and Chenopodium hybridum 632
cabbage B, site of carriage by Brevicoryne brassicae 649
cauliflower mosaic, in mustard, purification and properties 651
clover mosaic, physical and chemical properties 175, **176**
cucumber mosaic
in cherry, juice transmission to 85
in Nandina domestica, symptoms, virus characteristics and vector 569
transmission by phenol-water extracts of tissue 156
cucumber virus 1
in spinach, resistance to, new source 54
strain infectious to blight-resistant spinach 7
curly top, in cantaloupe, losses from late infection 327
Cymbidium mosaic, purification, electron microscopy, and properties 346, **347, 349**
disease of Hibbertia scandens 634
feathery mottle, in sweet potato, complex of 3—yellow dwarf, internal cork, and leafspot 751, **753**
from red clover, formation of local lesions on Gomphrena globosa 636
green ring mottle, in cherry, cause of epinasty reaction 495, **496**
hoja blanca, hosts and vector 643
hop mosaic, mild strain in hops 655
in apple, a sensitive indicator apple clone 646
in deciduous tree fruit nursery, importance of virus-free rootstock 240
in geranium, mechanical tranmission and host range 652
in sweet potato, in Israel 100, **101, 103**
infectivity dilution curve 89
inhibitors of, in rice 847
internal cork
in sweet potato
analysis for in serial nodes of stems 645
control by isolation 150
elimination by culturing apical meristems 840
part of feathery mottle complex 751, **753**
relation of insects to in Louisiana 447
leaf pucker virus, in sweet potato, in Israel 100, **101, 103**
leafspot, in sweet potato, part of feathery mottle complex 751, **753**
little cherry, reservoir of in flowering cherry 188
Mexican severe bean mosaic, in bean, interaction with potassium gibberellate 525, **526**
mosaic, in chrysanthemum, heat treatment 404, **406**
mottle leaf, in cherry, effect on free amino acids and amides 141
necrotic ringspot
differentiation from prune dwarf 635
in sour cherry, pollen transmission 624
new virus in blueberry 241
pea enation mosaic, transmission by phenol-water extracts of tissue 156
peach ringspot
in bean, topical susceptibility 659
in cucumber, topical susceptibility 659
peach yellow bud mosaic
in bean, topical susceptibility 659
in cowpea, topical susceptibility 659
pod mottle
differentiation by electron microscopy 656
inhibitors of in rice 847
possibly new virus, in bean, wide host range 655
potato F
host range, properties, varietal reaction, and resistance 642
in potato
resistance in interspecific hybrid 460, **462**
latent in imported variety 460, **462**
potato late-breaking, identity and host relations 312, **315**
potato X
crimson clover a new host 659

viruses potato X (continued)
in pepper, natural occurrence in California 650
inhibitors of in rice 847
transmission by phenol-water extracts of tissue 156
potato virus Y
field spread in south Florida 424, **425**
in pepper
genetics of resistance 364
a mutation for resistance 632
prune dwarf
differentiation from necrotic ringspot 635
in sour cherry, pollen transmission 624
radish yellows, range, vectors, and symptoms of hosts 389, **391**
raspberry mosaic, in wineberry, a wild host 570
rasp leaf, in cherry, effect on free amino acids and amides 141
ringspot
in cherry
separated from green ring mottle virus 495, **496**
effect on yields 412
in sweet potato
identifying with paper chromatography 98, **98**
in Israel 100, **101, 103**
in Prunus mahaleb, effect on free amino acids and amides 141
rose mosaic, in rose, heat treatment 240
severe bean mosiac, a new bean virus from Mexico 334, **335, 336**
southern bean mosaic, inhibitors of in rice 847
"spherical," differentiation by electron microscopy 656
spotted wilt, in cowpea, topical susceptibility 659
stem-pitting, in apple, bark patch grafts for indexing 241
stone fruit ringspot
evidence that it causes sour cherry yellows, prune dwarf, peach necrotic leafspot, muir dwarf, and peach stunt diseases 380
heat inactivation 380
strawberry complex, dissemination in Arkansas 477
streak virus, in pea, wide host range 654
stunt of apricot, relation to other stonefruit viruses 658
sweet potato mosaic
a strain of tobacco mosaic, additional evidence 709, **710**
etiology and characteristics 744, **745, 747**
sweet potato viruses, in seedlings as indicators, sweet potato and morning glory 571
tobacco etch
in Capsicum annuum, genetics of resistance 364
in pepper (Tabasco), pathological histology 658
tobacco mosaic
8-azaguanine on, effects on replication 884
electrophoresis on agar gels 82
effect of pH and milk on 638
in bean
topical susceptibility to cowpea strain 659
in Chenopodium murale, field occurrence 628
localized acquired resistance 741, **742**
in pepper
effect of air temperature on multiplication 803, **804, 805**
induction of necrotic pod streak 464, **465**
in tobacco
competition between two strains 659
difference in Nicotiana glauca form from dominant form 497, **498**
effect of plant nutrition on virus multiplication 26, **27**
induced resistance from infection 652
improved resistance 572
lesion size and timing from two strains 677
magnesium effect on multiplication 195, **196**
release and preservation by roots 111
strain interference 86
topical susceptibility 659
virus-host relations in tissue culture 587, **588, 589**
in tomato
field occurrence 628
viruses tobacco mosaic (continued)
four pathogenic strains 645
distinguishing internal browning from graywall 648
effect on yields 235
inactivation in tomato seed 627
induction of necrotic pod streak of pepper 464, **465**
inhibitors of in rice 847
multiplication, effect of pyrimidines and 5-phenylazopyrimidines 344
sweet potato mosaic a strain of, additional evidence 709, **710**
transmission by phenol-water extracts of tissue 156
bean strain in bean, release and preservation by roots 111
in bean, topical susceptibility 659
in cleome
release and preservation by roots 111
topical susceptibility 659
in cowpea, topical susceptibility 659
in cucumber, topical susceptibility 659
in tobacco, topical susceptibility 659
inhibitors of in rice 847
similar virus isolated from potato and soil 84
transmission by phenol-water extracts of tissue 156
tobacco-necrosis-like, isolated from potato and soil 84
tobacco ringspot
differentiation by electron microscopy 656
in bean, thought to be top necrosis virus from cantaloupe 576
in sweet potato, masked strain found 571
inhibitors of in rice 847
natural occurrence 296
transmission by phenol-water extracts of tissue 156
tomato bushy stunt, differentiation by electron microscopy 656
top necrosis of beans from cantaloupe, thought to be strain of tobacco ringspot 576
topical susceptibility to 659
turnip mosaic
from two weed hosts 578
purification 797, **800, 802**
turnip yellow mosaic, differentiation by electron microscopy 656
vein-clearing
in sweet potato
identifying with paper chromatography 98, **98**
in Israel, 100, **101, 103**
vein necrosis, inhibitors of in rice 847
Western X-disease, in peach, effect on free amino acids and amides 141
wheat streak mosaic, inhibitors of in rice 847
white clover mosaic, properties of Indiana isolate 711, **713, 716**
wound-tumor, in clover, biochemical studies of the root tumors 651
X
in potato
carbohydrate reserves in resistant plants 629
isolation from immune varieties 231
in milkweed, natural infection 636
yellow bud, in cucumber, topical susceptibility 659
yellow bud mosaic, mechanical transmission, recoveries, and various hosts 466, **468-471**
yellow dwarf
in oat, effect on winter killing 84
in sweet potato, part of feathery mottle complex 751, **753**
yellow patch, inhibitors of in rice 847
yellows, in cherry, effect on yields 412
Wadley, Bryce N. 87
Wagnon, H. Keith 658
Wahl, I. 562
Walker, J. C. (198), (360), (367), (370), (648)
Walker, Jerry T. 658
Wallace, A. T. (205)
Ward, C. H. 658

watermelon, Geotrichum candidum in, susceptible to most isolates tested 665, **667, 668, 671**
Waton, R. D. 792
Watson, W. M. (40)
Way, R. D. (624)
Weathers, L. G. 87
Weaver, M. L. (161)
Webb, R. E. (7), 54
Weber, G. F. (631)
Weber, P. V. V. 235
Weinstein, Leonard H. (651)
Welkie, G. W. (82)
Wester, R. E. 573
western gall rust, see (under fungi) **Peridermium harknessii**
wheat
barley stripe mosaic virus in, effect of temperature and host age on disease and seed infection 290, **292**
Erysiphe graminis in, inhibition by antibiotic produced by Streptomyces sp. 841
Erysiphe graminis tritici in, genetic control of host-parasite relations 454
extracts from healthy plants, antigenic analysis 646
Helminthosporium sativum in, pathogenic specialization 627
hoja blanca virus in, transmission by Sogata orizicola 643
Puccinia coronata avenae in, induced susceptibility to 630
Puccinia graminis avenae in, induced susceptibility to 630
Puccinia graminis tritici in
development in leaves treated with sugars and sugar alcohols 114, **116**
effect of $NiCl_2$ on plant development 640
half-life of representative systemic chemicals 627
inhibition by antibiotic produced by Streptomyces sp. 841
metabolic changes in host 636
nature and turnover of organic acids in 643
predisposition of seedlings 339, **339**
relations between inoculum density and infection 86
survival of races near barberry 40
survival of urediospores on dry foliage 400
toxin extracted from 130, **131, 133**
Puccinia rubigo-vera in, inhibition by antibiotic produced by Streptomyces sp. 841
residues of, effect on soil fungi 22
seedling blight, effect of growing crops and crop residues on 22
Septoria tritici in
wheat Septoria tritici in (continued)
losses from 630
tests for resistance 654
stem rust in, effect of light and temperature on reaction 645
Tilletia caries in
effect of postinfection environment 651
seed treatment, fungicide vapor action ineffective 581
Ustilago tritici in, root and shoot development 645
wheat stem rust, see (under fungi) **Puccinia graminis tritici**
Wheeler, H. E. (205)
Whidden, Rodney (635)
Whipple, F. O. (83)
White, J. C. 658
Whitehead, Marvin D. (136)
Wilcox, L. V., Jr. 241
Wilcoxson, Roy D. (636), **(636)**
Wildman, S. G. 677
Wiles, A. B. 658
Wilhelm, Stephen (772)
Wilks, J. M. 188
Williams, E. B. (640), (844)
Williams, Lansing E. 22, (212), 658
Williams, Leonard F. (136)
Williamson, C. E. 659
Willis, C. B. 659
Wilson, C. W. (642)
Wilson, E. E. (646), (646), (649)
Wilson, Eugene M. 607
Wilson, J. B. 574
wineberry, raspberry mosaic in, a wild host 570
Winstead, N. N. (583), 659, (781)
witchweed, penetration and nutrition of 652
Wood, Francis A. 659
Woodcock, W. P. 242
Wright, W. R. (474)
Wu, Jia-Hsi 587, 659
Wu, Lung-chi (594)
Yamada, H. (30)
Yarwood, C. E. 111, 659, 659, 741
Yerkes, William D., Jr. 334, 525
Young, P. A. 577, 578
Young, Roy A. (83), (85), (386)
Zaumeyer, W. J. 226, 574, (847)
Zeiders, K. E. (757)
Zentmyer, G. A. (83)
Zentmyer, George A. 87, 421, 660, 660

ERRATA, VOLUME 49

Page 387 table 2 title line 2: *read* 9 *for* 11

Page 656 Fig. 1 caption: *read* E *for* D, *and* D *for* E

Page 659 column 1 line 1: *read* 1-E *for* 1-D

Page 659 column 1 line 14 from bottom: *read* 1-D *for* 1-E

Page 679 citation 11 line 3: *read* Växtskyddsanstalt *for* Vöxtskyddsanstalt

Page 679 citation 16: *read* Müller *for* Muller

Page 719 column 2 line 5: *read* reproduce *for* produce

Page 764 column 1 line 10 from bottom: *read* the fungus appears *for* appears

ERRATA, VOLUME 50

Page 1 column 2 line 13: *read* crested *for* created

Page 10 column 2 line 14 from bottom: *read* were available in quantities *for* were quantities

Page 11 column 2 line 12: *read* Lowry *for* Lowery

Page 12 fig. 1 caption line 11: *read* μM for *M*

Page 12 fig. 1 caption line 5 from bottom: *read* μM *for* *M*

Page 21 citation 22: *read* α-Ketoglutaric *for* -ketoglutaric

Page 22 authors' address: *read* Department of Botany and Plant Pathology

Page 67 column 2 line 8: *read* indirect *for* direct.

Page 120 column 2 line 22 from bottom: *read* (E. F. Sm.) *for* (E. F. Sm.

Page 121 column 1 line 8 from bottom: *read* slant *for* plant

Page 123 authors' address first line: *read* Especiales *for* Espiales

Page 130 second article column 2 line 2: *read* stain *for* strain

Page 158 column 2 line 4 from bottom: *read* nodulosum *for* nodulos

Page 163 second article line 17: *read* Endoconidiophora *for* Endothia

Page 172 table 2 footnote *a* line 5: read trial II *for* trial H

Page 185 table 1 footnote *a*: *read* nitrite in *for* nitrate in

Page 216 column 1 line 5: *read* the acid *for* the acetic acid

Page 225 page heading: *read* FLOR *for* FLORA

Page 243 column 2 line 16: *add the name* Ellen L. Moorhead

Page 337 table 4 line 13 "Mexican virus" column "Transmissions": *read* M *for* MS

Page 364 "Introduction" line 2: *read* resistance in *for* resistance to

Page 411 column 1 line 2 from bottom: *read* 235673 *for* 23567, *and* 183692 *for* 18369

Page 411 column 1 line 7 from bottom: *read* 183692 *for* 18369

Page 411 table 3 bottom line: *read* 183692 *for* 18369

Page 480 "Introduction" line 5: *read* (3) *for* (13)

Page 530 table 5: *move subhead* Susceptible *from below rule to above it, and move* Germ-tube *to below rule, directly above* length (μ)

Page 562 second article column 2 line 15 from bottom: *read* variety avenae *for* variety of avenae

Page 563 column 1 line 11 from bottom: *read* excrete *for* excretes

Page 566 citation 2: *read* Uredineen *for* Uredinen

Page 574 column 1 line 3 from bottom: *read* scab *for* scale

Page 574 column 1 line 15 from bottom: *read* 2 lb *for* 2 gal.

Page 588 column 2 line 20 from bottom: *read* 0.2 μg *for* 2 mg

Page 608 column 1 line 15 from bottom: *read* conidia *for* conidium

Page 627 column 1 line 17: *read* 100 ml *for* 10 ml

Page 640 column 1 line 5: *read* 1:3 *for* 1:1

Page 643 column 2 first full abstract line 8 from bottom: *read* rice *for* rye

Page 643 column 2 first full abstract line 9 from bottom: *read* rye *for* rice

Page 747 fig. 3 is upside down

At the root of a $100,000,000 problem...

Smaller than these dots . . . the nematode is destructive enough to cause more annual damage to agriculture than any insect known to man.

Nematodes choke off the roots of plants so that nourishment which would normally be gained from the soil is severely reduced. When nematodes invade a field, the plants wither, their growth is stunted and in extreme cases the plants die.

Shell Chemical Company, a pioneer in the field of nematology, working closely with federal, state and local agricultural specialists, has developed two outstanding soil fumigants for protecting plants from nematode damage. They are D-D® Soil Fumigant for preplanting application and Nemagon® Soil Fumigant, a potent soil fumigant which can be used for treating living plants. Both of these products have been used by farmers all over the world in the never-ending battle against the nematode.

This is just another example of how Shell Chemical Company is helping the agricultural community grow bigger, better yields for a growing America.

SHELL CHEMICAL COMPANY

AGRICULTURAL CHEMICALS DIVISION
110 West 51st Street, New York 20, New York

SHELL

DIFCO

Media for

MYCOLOGY

DIAGNOSTIC

. . . for the isolation, identfiication and cultivation of pathogenic fungi. These media are also widely used in phytopathological studies. Several are neutral in reaction, giving optimum conditions for growth of a variety of fungi. The following may be prepared as selective media by the adjustment of reaction, addition of antibiotics or other agents:

Bacto-Brain Heart Infusion Agar
Bacto-Sabouraud Dextrose Agar
Bacto-Sabouraud Maltose Agar
Bacto-Littman Oxgall Agar
Bacto-Mycological Agar
Bacto-Mycological Broth
Bacto-Corn Meal Agar
Bacto-Corn Meal Agar with Dextrose
Bacto-Bean Pod Agar
Bacto-Prune Agar
Bacto-Lima Bean Agar

CONTROL

. . . for sanitary and sterility procedures as well as for general use in mycological procedures:

Bacto-Sabouraud Maltose Broth
Bacto-Sabouraud Liquid Medium
Bacto-Malt Extract
Bacto-Malt Agar
Bacto-Neurospora Culture Agar
Bacto-Potato Dextrose Agar
Bacto-Mildew Test Medium
Bacto-W.L. Nutrient Medium
Bacto-W.L. Differential Medium

CLASSIFICATION

. . . and nutritional studies of fungi:

Bacto-Yeast Morphology Agar
Bacto-Yeast Carbon Base
Bacto-Yeast Nitrogen Base
Bacto-Czapek Dox Broth
Bacto-Czapek Solution Agar
Bacto-Vitamin Free Yeast Base

THE DIFCO MANUAL, *NINTH EDITION,*
including descriptions of these media and their use,
is available on request.

DIFCO LABORATORIES

DETROIT 1, MICHIGAN